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STABILITY INFORMATION FOR THE MASTER

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FINAL REPORT

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16. Abstract

This paper explores the current and optimum content and formats of ships' trim and stability booklets, using naturalistic observation and documentary analysis. An optimum Trim and Stability booklet is proposed, together with graphic standards and guidelines for maximum comprehensibility.

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METRIC CONVERSION FACTORS

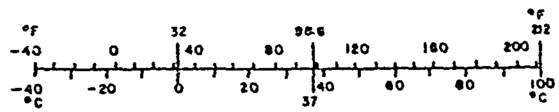
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION AND BACKGROUND

1.1 Case Study

Marine operating practice places a great burden on the understanding of licensed officers and their ability to deal with routine and emergency operational matters. After the studies and examination for a license are completed, very little explicit operational guidance is available to officers. This is in direct contrast to the airline industry, where flight procedures are reviewed in detail by the responsible regulatory bodies.

The stability-related material provided for officers' guidance includes trim and stability booklets, loading/operating manuals, hazardous cargo data, and occasionally damaged stability data.

The trim and stability booklet (or manual, usually referred to as the T&S booklet) is a Coast Guard-approved compendium of operational guidance, which is furnished primarily to allow safe vessel operation. Simple vessels - mostly barges - may have a mere stability letter, specifying the load draft and disposition of cargo. The operations of commercial vessels which are the subject of this report require a more detailed treatment. The resulting T&S booklet has expanded from a mere leaflet to, in some cases, a series of substantial simply-bound volumes. It may be combined with a legally-required operations manual. This is largely concerned with assessment of strength and is reviewed by the appropriate classification society. The terminology of 'booklet' and 'manual' is very lax, reflecting the proliferation of Goast Guard, ABS, and company manuals, all aimed at various aspects of operational safety and overlapping in several areas. Most of this is presented in technical form, as background and technical reference material. Evidently, the belief

is that if the master is adequately supported with engineering, then his judgement will be the best protection of the vessel, crew, and cargo.

This attitude has been justified to the extent that there have been few modern losses due to lack of stability. However, it ignores the fact that little time can be devoted to learning to use stability-related material or to becoming adept in pre-computing important stability parameters. Adequate attention to stability and trim has, does, and always will contribute to safe and effective marine transportation. Nevertheless, stability and trim calculations usually occupy a very small amount of the working time of the ship's crew, whose primary job is, after all, to sail, dock, undock, and keep the vessel in repair. Their secondary job - documenting all these tasks - is also becoming more time-consuming. Masters, for example, spend a large proportion of their time doing the payroll if no purser is on board. Chief mates, in turn, spend much of their working time dealing with cargo paper work (containerships), or in physically supervising the cargo operations (LASH ships, tankers, and break bulk ships). These same chief officers and masters must make time to perform and review the stability calculations. Under these circumstances, less emphasis on advice and more emphasis on instructions probably would be appreciated.

Because stability booklets' guidance is couched in terms of advice rather than instruction (see Table 1), there is little uniformity in vessel operations. Chief mates and captains may ballast the same vessel, with the same cargo, in entirely different patterms. Some masters and mates feel more secure with a large GM, some feel a lower GM reduces rolling, some rely on terminals' cargo

GENERAL STABILITY COMMENTS

During loading/unloading operations, the transverse metacentric height, GM_T, must always be positive (sluice valves open). If the GM_T is negative, the vessel is not stable and may heel over to a large angle before stable equilibrium is reached.

In addition, sufficient initial GM_T must be available (after closing sluice valves) to prevent excessive heel or progressive flooding thru openings on the main deck if the vessel is damaged and flooding occurs.

At sea, sufficient positive initial GM_T must be available to prevent excessive heel or progressive flooding if the vessel is damaged and flooding occurs.

11. The ship shall be loaded at the start of any voyage such that boiloff and the use of consumables during the voyage will not result in the KG becoming greater than the maximum allowable KG. In general, the more critical loading conditions are those with full cargo aboard, with high density LNG being most critical. The following measures may be taken to improve KG:

    a) Ballast with salt water. This measure adds weight low in the ship. However, slack ballast tanks can create significant free surface effects as well. The combination of these two effects may cause a net INCREASE in KG rather than decrease. The "Net Effect on KG by Filling Tanks" tables on pages 9-12 should be used as a guide to determine the most advantageous ballasting methods. Ballasting to improve stability shall not cause the load line draft of 37 ft. 10 in. to be exceeded. Ballast stabilizer tanks No. 5, 7 and 9 shall not be used to attempt to improve KG or alter trim by filling to any level except operating level.

    b) Locate fuel in forward Fuel Tanks No. 1 and 2. Fuel Tanks No. 1 and 2 have lower centers of gravity than wing Fuel Tanks No. 5 and 6. Fueling the forward tanks will also reduce the tendency to trim by the stern. The trim table on page 3 may be used to determine trim changes.

    c) Empty the Full Load Roll Stabilizer, Tank No. 8¢. This measure reduces the free surface correction factor and thereby decreases KG and improves stability. Increased roll amplitudes should be expected at sea, however. (Refer to "Instructions for Operating Roll Stabilization System".) Use Curve 2 or 3 on page 4.

    d) Ballasting or deballasting at sea to improve trim or stability should be avoided where possible by pre-planning the entire voyage. However, if necessary, ballast tanks other than Stabilizer Tanks 5, 7 and 9 may be filled or emptied at sea providing it is done in a rapid and continuous manner, only one pair of wing tanks is changed at a time, and the tanks are either pressed full or pumped to minimum content (stripped)

TABLE 1 - EXERPTS FROM T&S BOOKLET INSTRUCTIONS

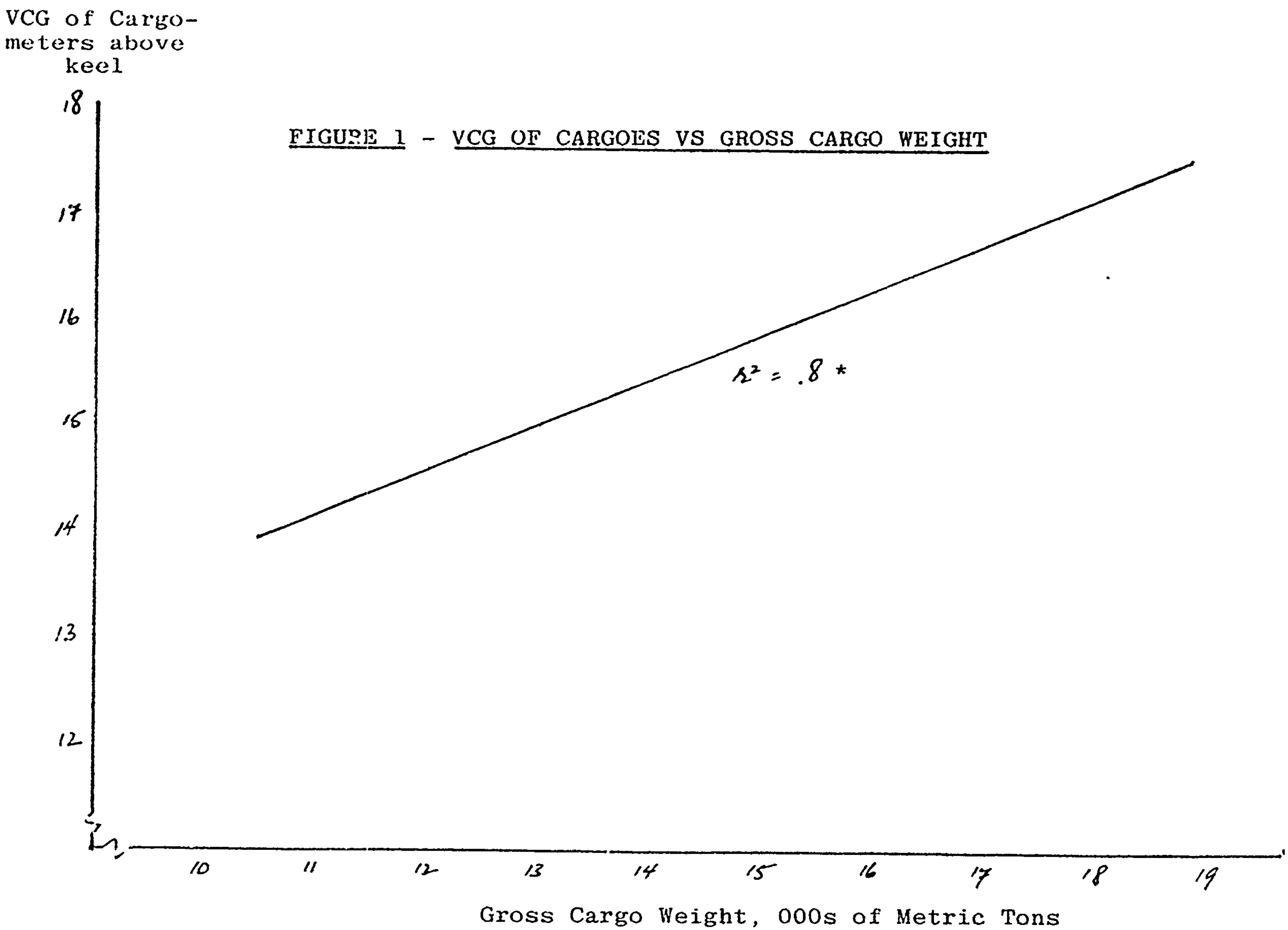
Note lack of proposed optimal course of action or basis for choice of action(s).

weights more than others do. This partially defeats one of the purposes of the booklet - ensuring that operations are efficient as well as safe. One would expect that techniques of vessel stability calculations, interpretation of results, and management of fuel and ballast were sufficiently well developed and explained so that officers would follow similar courses when presented with the same situation.

This is not the case, at least with containerships. In 1979, E. G. Frankel Inc. performed a proprietary study for a major transAtlantic container operator dealing with the ballast and fuel management practices. The study showed that while the vertical center of gravity of the cargo on board was extremely predictable from the gross weight of the cargo (see Figure 1), the amount of ballast and fuel in the ship was very unpredictable (see Figure 2). A year-long program of improvements in trim and stability calculation methodologies, and education in principles of seakeeping in general was instituted. This not only reduced the average amount of ballast carried, but doubled the predictability of ballast and fuel weights (see Figure 3). The improvement was largely due to the company's emphasis on technical justification of decisions and reduction of pure "judgement".

A significant finding of the study was that the vessel's trim and stability book had proved to be completely unsatisfactory for its primary intended purpose (operational safety). On all vessels, it was observed that the loading calculations were made using the capacity plan for information. On two vessels, in fact, three hours were required to find the trim and stability book. While these findings are perhaps not generalizable to all vessels, it seems a pity that in this case - and by inference many others - the effort which went into the

FIGURE 1 - VCG OF CARGOES VS GROSS CARGO WEIGHT



* i.e. VCG of cargo and cargo weight correlate highly (.8) and one can be predicted from the other

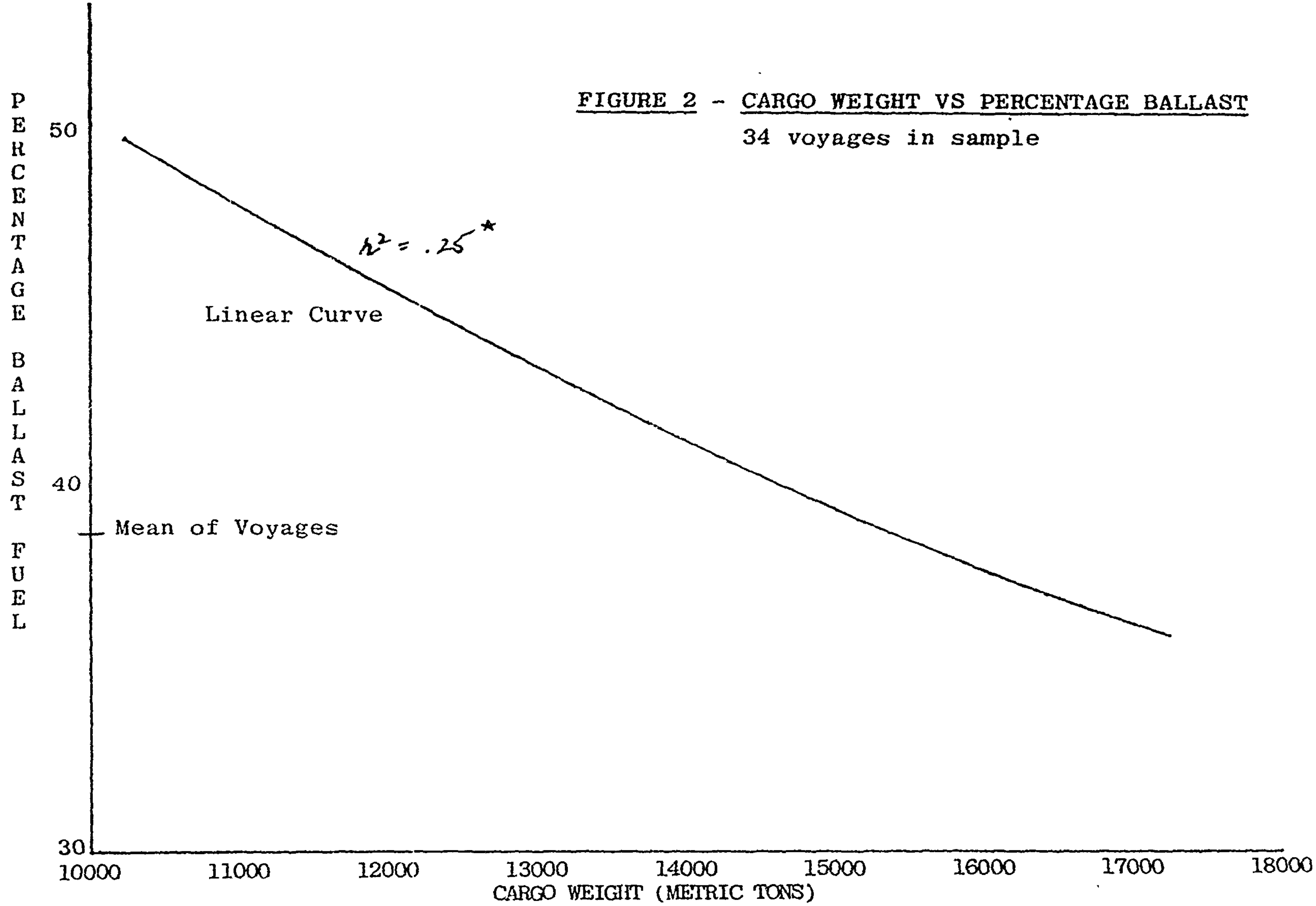
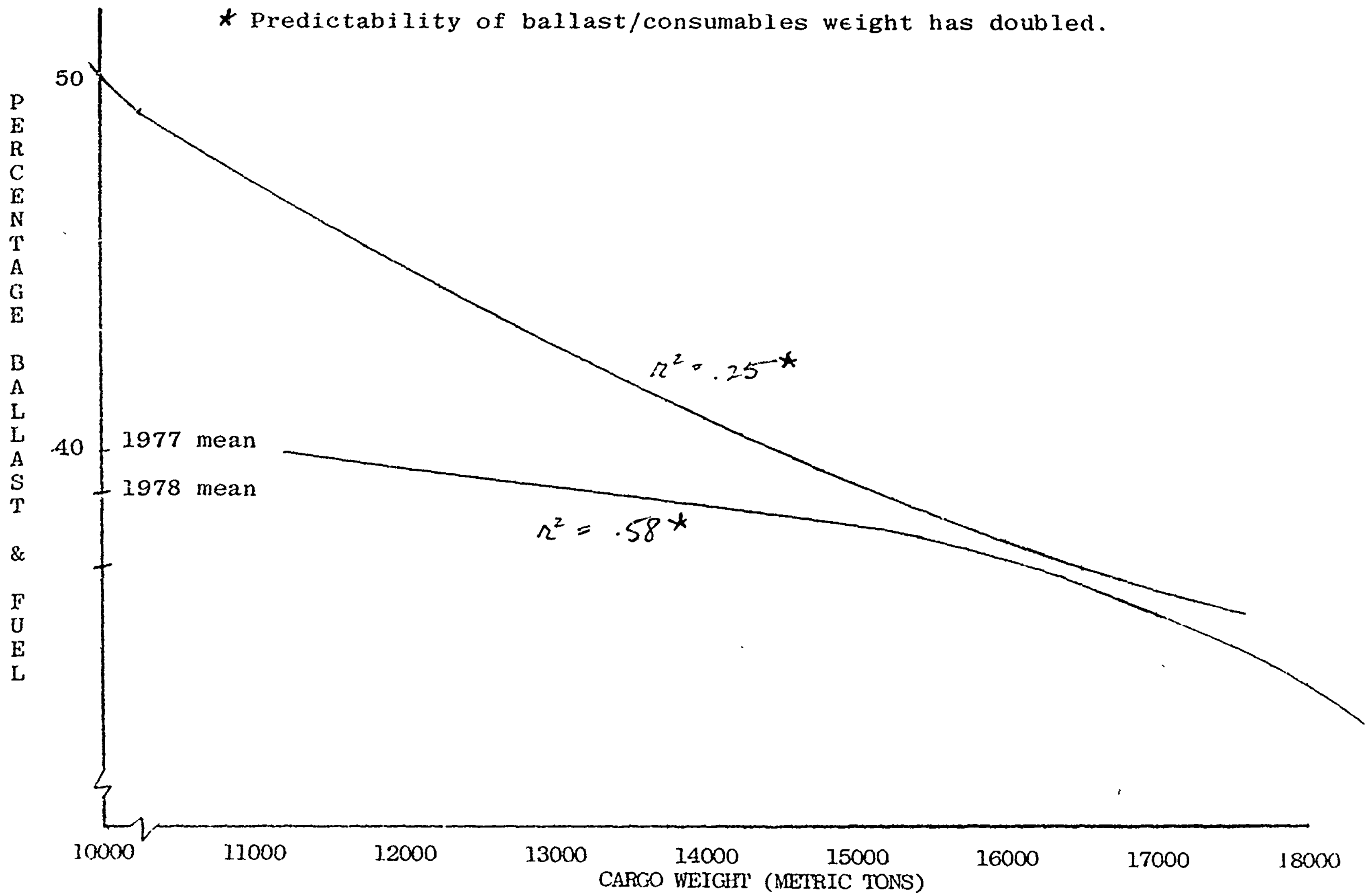


FIGURE 2 - CARGO WEIGHT VS PERCENTAGE BALLAST

34 voyages in sample

* regression coefficient of .25 indicates that percentage of consumables cannot be predicted well from cargo weights.

FIGURE 3 - COMPARISON 1977 AND 1978 RESULTS



* the increased correlation coefficient - .25 to .58--indicates that the predictability of fuel/ballast proportion has been doubled

initial T&S booklet was wasted. Considering that only a few items of specific guidance material are provided, it seems clear that providing the officers with usable, relevant material should be a priority of shore-based engineering and operational personnel.

It was clear that in the operator's case, the fundamental reason for the neglect of the T&S book was divergent goals of the maker and users. The official goal was to provide a trim and stability book ensuring the safety of the vessel and to prevent capsizing in a storm or through collision damage to the hull. The ship's crew and the shore staff hoped (and failed) to use the booklet to load the vessel and to minimize rolling angles in normal sea conditions. While these goals are complementary, they are nevertheless different goals, which are satisfied by different material.

The implications of this study for the present enquiry are manifold, but two stand out. Firstly, it is clear that a T&S booklet which is to perform as intended (particularly in securing vessel safety) must be easy and quick for the officer to *familiarize* himself with. Secondly, the methods and presentations must reflect the extreme pressures on officers' time in port, and be immediately intelligible if possible, certainly self-contained. These factors clearly imply that conventional T&S booklets require format and content changes to remain/become effective.

1.2 Background

The purposes of the present study are to determine (i) the optimum format and content of trim and stability and trim and longitudinal strength booklets, (ii) the presentations of governing parameters which are easiest

for users to understand, and (iii) the methods of calculation which yield the fastest and most reliable results in assessing the effects and safety of specific vessel operations. The recommendations cannot be offered without some reference to the use made of electronic aids, although the booklet is and must remain independent of any and all aids. In addition to these overall recommendations, solutions to specific problems in the use of stability information will be proposed and optimized with respect to the method and costs of implementation.

Historically, efforts to improve the calculation of vessel stability began with simple mechanical devices such as mimics to aid the ship's officers. Before World War II, actual metal profiles of the vessel and scaled-down cargo weights were used to explore safe loading conditions. After 1950, more sophisticated yet still relatively simple devices for calculating stability, such as the Ralston loading calculator, or later, the Loadicator, were commonly provided. Given the size of average individual lifts, and the typical hourly rates achieved by '50s vessels, these materials - providing inputs or adjuncts to hand calculations - were adequate.

Following a series of casualties and oeprational problems with war-built ships in the late 40's and early 50's, it was required that major merchant ships be supplied with a trim and stability booklet incorporating loading instructions.

The general purpose cargo or tankship was able to meet its needs for stability information with these relatively brief, simple T&S booklets. This was due to the simplicity and slowness of operations. While many more units of cargo were loaded, in the case of general

cargo ships, these were stowed by the mate and one often hears it said that these cargoes could be 'eyeballed' - allocated between hold and tween deck on a commonsense basis, taking the obvious nature of the commodity into account. The older '50s type of T&S booklet, i.e. the booklets of old freighters and T2 tankers,* typically contains vessel particulars, instructions, a curve of required GM, hydrostatics, cargo and tank capacities and VCGs, but the level of detail is lower. Generally, there are fewer compartments, tank properties are not tabulated by depth, and a greater margin of GM is sometimes required. Older booklets make only one determination of (midships) bending moment, if any. The size and scantlings of these vessels means that the shear forces associated with acceptable bending moments are within design limits. Consequently, shear forces are not treated in the booklet, since they do not govern vessel safety.

The evolution of parcel and ULCC tankers and the advent of container ships, barge carriers, and other specialized types of vessels - with exacting stability and strength requirements - has been paralleled by operational requirements which make the problem of monitoring stability more onerous. A more complex booklet is needed: the sample listings and calculation instructions of the older booklets are inadequate to the officers' information needs.

The legislation governing stability considerations has grown in volume and complexity. It now reflects an awareness of international stability standards, as expressed in SOLAS conventions and the various anti-pollution conventions

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* See the (Sample) Stability Booklet, S/S General Cargo, by MarAd.

developed under IMCO auspices. The range and severity of stability conditions experienced by the ship in service has increased, because of dimensional and powering changes, and emphasis on schedule keeping. The changing requirements for ship operation are a further complicating factor. Cargo and replenishing operations proceed much more quickly, and require continuous detailed monitoring. An LNG tanker, for example, must be able to leave the port immediately, at any time during operations, if she is to comply with port regulations. The size and draft of vessels has increased to such an extent that vessels are now operated very close to the physical limits of harbors and docks, and at speeds which sensitize them to effects of handling phenomena such as squat and interaction, which are affected by trim, draft, and other loaded conditions (e.g. sagging and hogging).

The operational changes have brought more organizational units into the task of stability calculations - terminals, central cargo coordinating units, surveyors - and have also required higher, faster levels of individual performance. The contribution of the booklet to individual performance is central, and can be increased by reformatting and adjusting the content. This is a major concern of the present study.

Most ships' officers are unaware of the amount of calculation, and simulation of vessel conditions, which is performed during the process of designing and building a ship. Clearly, much more information is generated during the design process than appears in the T&S booklet. The selection which is incorporated in a specific T&S booklet reflects, first of all, legal requirements, and secondly, owner preferences.

The legal requirement is complicated by the fact

that vessel is classed, and the Load Line is assigned, by ABS acting as authorized agent of the Coast Guard. This assignment of a Load Line implies compliance with strength and other requirements for the vessel class, and the vessel is accordingly provided with an ABS-approved method of calculating strength and an appropriate strength criterion, which incorporates allowances for calculation inaccuracies and other probable circumstances. The strength requirements and bending moment calculations *for most commercial service vessels* are not reviewed by the Coast Guard for Load Line and classification, and are frequently in a separate "Loading Manual", rather than in the T&S booklet itself.

Owner's preferences are frequently expressed in both form and contents of booklets. Voyage examples may reflect a specific range of possible trades; conversely, the booklet may reflect dedication to one trade with a restricted range of cargoes. There are also characteristic treatments of lightship, stores, bunker assumptions, etc., which are familiar to masters and mates of a given company. Understandably, owners wish to retain these distinctive features, which may or may not be operationally highly significant. An allied issue is the form and appropriate location of the operational guidance which is required for efficient vessel operation. Formerly the "Operating Instructions" in the T&S booklet were the sole source, and largely confined themselves to such instructions as were necessary for safety. At present, many ships are supplied with "operations manuals" which offer more detailed guidance, including some safety instructions. The dividing line between operational and safety instructions is finely drawn in some cases, and the proliferation of 'safety' - 'T&S' - operating - etc.

manuals does not seem desirable.

In the present review of T&S booklets, and recommendation of alternative formats, both the availability of additional information and the possibility of generating inexpensive alternative presentations will be considered. The scope for owner's preferences will be discussed in Section 7.0, but at this time it is appropriate to consider the governing criterion of the format and contents of the existing T&S booklet, the legislative requirements for stability information aboard ship.

1.3 Legislative and Regulatory Requirements

The legislative and regulatory requirements for stability information aboard ship stem from two sources, 46 USC 391 (RS 4417) and the enabling legislation for the various SOLAS and Load Line conventions which have been ratified by the United States (i.e. enacted by the Senate). It is interesting to note, however, that there is no explicit U.S. code devoted to the definition of stability requirements. The legal basis for stability requirements as expressed by subdivision, freeboard, and load lines, for example, is found in general law and enabling legislation.

SOLAS 1974 states the requirements for stability information to be supplied to the master in Chapter II-1, Part B - Subdivision and Stability. It should be noted that Chapter II-1 Part B of SOLAS 1974 applies to passenger ships only, except for Regulation 19, which also applies to cargo ships. Regulation 10 of the 1966 Load Line Convention requires stability information to be furnished to the master, and is applicable to merchant vessels in general.

Regulation 19 of SOLAS (Stability information for

passenger ships and cargo ships) and Regulation 10 of the Load Line Convention (Information to be supplied to the master) are particularly germane to this study, and are quoted here.

Regulation 19 (SOLAS 74)

Stability Information for Passenger Ships and Cargo Ships

> (a) Every passenger ship and cargo ship shall be inclined upon its completion and the elements of its stability determined. The master shall be supplied with such reliable information as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service, and a copy shall be furnished to the Administration.
>
> (b) Where any alterations are made to a ship so as to materially affect the stability information supplied to the master, amended stability information shall be provided. If necessary the ship shall be re-inclined.
>
> (c) The Administration may allow the inclining test of an individual ship to be dispensed with provided basic stability data are available from the inclining test of a sister ship and it is shown to the satisfaction of the Administration that reliable stability information for the exempted ship can be obtained from such basic data.
>
> (d) The Administration may also allow the inclining test of an individual ship or calss of ships, especially designed for the carriage of liquids or ore in bulk, to be dispensed with when reference to existing data for similar ships clearly indicate that due to the ship's proportions and arrangements more than sufficient metacentric height will be available in all probable loading conditions.

Regulation 10 (International Load Line Convention 66)

> Information to be supplied to the Master
>
> (1) The master of every new ship shall be supplied with sufficient information, in an approved form to enable him to arrange for the loading and ballasting of his ship in such a way as to avoid

> the creation of any unacceptable stresses in the ship's structure, provided that this requirement need not apply to any particular length, design or class of ship where the Administration considers it to be necessary.
>
> (2) The master of every new ship which is not already provided with stability information under an international convention for the safety of life at sea in force shall be supplied with sufficient information in an approved form to give him guidance as to the stability of the ship under varying conditions of service, and a copy shall be furnished to the Administration.

Title 46 of the Code of Federal Regulations, Parts 31, 74, 93, and 179, of Subchapter D, H, I, and T, respectively, lay down the requirement for the inclining test and the stability information for cargo, tank, and passenger ships. It is the responsibility of the Officer in Charge of Marine Inspection to insure that stability information for the master is placed aboard inspected ships.[1] The information requirements and stability criteria resulting from application of these general regulations are "...a rationalization of past experience"[2] and compliance does not "...ensure immunity against capsizing regardless of the circumstances or absolve the master from his responsibilities." The ship's master is still required to exercise "...prudence and good seamanship...(and) take the appropriate action as to speed and course warranted by the prevailing circumstances", and to verify that the amount and disposition of cargo accepted conforms to the stability requirements, which may be increased after evaluation of the possible events of the voyages.

Table 2 summarizes the CFR requirements for stability information on cargo, tank, and passenger ships. This is

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[1] See Table 3 - Procedure for Approval.

[2] Quotations are from various stability-related Navigational Inspection Circular notices.

TABLE 2

STABILITY INFORMATION - LEGAL REQUIREMENTS

VESSEL TYPE	REQUIREMENTS FOR INCLINING TEST	PLANS REQUIRED BY USCG FOR STABILITY ASSESSMENT *	STABILITY STANDARD	INFORMATION SUPPLIED TO MASTER IN ADDITION TO LOADING MANUAL
TANK SHIP	Vessel's stability is reviewed; inclining test is at Commandant's discretion, if "...the assumption is made that the center of gravity of the ship while in a light-weight condition is located a vertical distance of at least 0.7 times the molded depth of the ship from the keel amidships or from a horizontal plane tangent to the keel amidships".	line plan curves of form general arrangement plans inboard and outboard profiles midship section tank sounding tables draft mark locations capacity plan - capacity, LCG and VCG of all compartments	Tankers must comply with damaged stability requirements of 46 CFR 42.20-5 (1966 Load Line Convention) and 33 CFR 157.21 which aim at pollution abatement as well as safety. Intact and damaged stability requirements as laid down in 46 CFR 153 apply to chemical tankers.	Stability letter - approving "information, based upon the results of the applicable stability test, which is such that the master can, by rapid and simple process, obtain accurate guidance as to the stability of the vessel under varying conditions of service." Special operating requirements must be expressly addressed.
CARGO/MISC. VESSELS	Inclining test is required unless approved sister ship data is substituted. Bulk carriers, like tankers, may be exempted "...when reference to existing data for similar vessels clearly indicates that...sufficient metacentric height will be available in all probable loading conditions".	"	Vessel assigned curve of minimum GM which incorporates weather (46 CFR 93.07-10) and damage (46 CFR 42.20-10) criteria as applicable to individual vessel. General cargo vessels carrying bulk grain are subject to 46 CFR 93.20 (incorporating 74 SOLAS convention and related U.S. regulations).	"...stability letter and data necessary to permit effective handling of the vessel...obtain accurate guidance as to the stability of the vessel and determine the freeboard." Special operating requirements must be expressly addressed.
PASSENGER VESSELS	International Voyage. all vessels rquire test unless approved sister ship data is substituted. Voyages other than international. inclining test is at Commandant's discretion, where "due to the form, construction, and arrangement of the vessel stability calculations can be safely made without a stability test being performed."	"	Intact Stability: §74.10-5 or 74.10-10 - whichever is most severe - both yield minimum GM. Damaged Stability: §74.10-15.	Stability letter and booklet, giving 1) information required to assess intact stability of the vessel under varying conditions of service; 2) indication of extent of damage vessel is computed to be capable of withstanding; 3) cross flooding instructions where such arrangements exist.

* see overleaf.

TABLE 2

(continued)

- Plans Required by USCG. Plans required for the test are listed in the regulations, however, information is sometimes omitted from these plans. Due regard to the following terms will either avoid unnecessary delays, or will otherwise speed up plan review.

1. Lines Drawing. Lines information is processed by computer. Ten or more evenly spaced stations with one or two half stations at the ends, and a table of waterplane offsets, will facilitate review.
2. Curves of Form. Curves of form should be prepared to a scale of values sufficiently large for the purpose intended and should include:
   a. Baseline information (keel, molded, or other)
   b. Displacement - molded and with sheel and appendages (indicate fresh or salt water)
   c. Longitudinal Center of Buoyancy
   d. Vertical Center of Buoyancy
   e. Longitudinal Center of Flotation
   f. Tons per Inch Immersion
   g. Moment to Trim One Inch
   h. Height to Transverse Metacenter
3. Midship Section. The midship section drawing should show molded depth, thickness of deck plate, and keel plate, gunwale assembly including bulwark, fenders, etc. This information is necessary to determine hog or sag.
4. Tank Tables. These plans should show the locations of the sounding tubes, thickness of striker plates, as well as sections and elevations in way of the sounding tubes.

TABLE 3 - PROCEDURES FOR APPROVING STABILITY INFORMATION IN THE ISSUANCE OF LOAD LINE CERTIFICATES

Category of Vessel	Coast Guard-Inspected Vessels		Uninspected Vessels	
	Manned	Unmanned	U. S. Flag	Foreign Flag (Form B)
Extent of analysis required	Inclining experiment, intact stability calculations, and information to the Master concerning the vessel's stability Note: An inclining experiment may be waived on barge type hulls		Same as inspected vessels	Stability information approved by another administration, OR Same as inspected vessels
Form in which information is to be passed to assigning authority	Copy of the stability letter issued by CG to Master (Load Line Certificate to be issued only if route and service are as stated)	Letter by CG stating what information required on board the vessel OR Copy of stability letter issued by CG	Letter by CG stating what information is required on board the vessel OR Copy of stability letter issued by CG	Copy of stability information approved by another administration and stamped "Examined" by CG OR Letter by CG stating what information is required on board the vessel
Responsibility for assuring that the required stability information is aboard the vessel	Placed aboard by the cognizant OCMI	Stability information will be included by endorsement on the Load Line Certificate by the assigning authority OR The assigning authority must assure itself that the stability information approved by the Coast Guard or another administration is aboard the vessel before issuing a Load Line Certificate		

Source: Enclosure (1) to NVC 4-74

provided in the form of a stability letter and booklet. The primary objective of the information is to ensure adequate transverse stability, since capsizing is relatively easily brought about by improper or inattentive ship operations, such as cargo handling, fuelling, and ballasting. The CFR description of information to be supplied to the master is general, and the stability booklet requirements which have been developed have been periodically modified by instruments such as NVIC circulars, which identify and promulgate new information concerning safe operational practices. The legal requirements for stability information assume that the vessel's design incorporates regulatory body and classification society criteria which include, inter alia, the combined interactive effects of reserve buoyancy, freeboard, and GM on intact and damaged stability.

Title 46* and 33 also addresses the intact and damaged stability requirements of 1) self-propelled vessels carrying dangerous bulk cargoes and liquid gases, and 2) diverse categories of marine vessels and idiosyncratic requirements (e.g. mobile offshore drilling units, schoolships). It was decided that only the former could be effectively addressed in this study. Overall tank vessel stability (46 CFR Subchapter D) criteria apply, but the vessel must in addition meet the requirements of 46 CFR Subchapter O, Parts 151, 153, or 154 as required, to have its certificate of inspection endorsed for a dangerous cargo. These subchapters prescribe the extent of damage which must be sustainable for given hull types,

* Title	Subchapter	Part	Subject
46	I-A	108	Mobile Offshore Drilling Units
46	O	151	Chemical Barges
46	O	153	Chemical Ships
46	O	154	Gas Ships/Barges
46	R	167	Public Navt. School Ships
46	R	168	Civilian Navt. School Ships
46	U	191	Oceanographic
33	O	157	Oil Tank Vessels

defining the permeability, free surface, and other assumptions to be employed in the damage calculations.

1.4 Operational Requirements

In order to develop appropriate courses of action, what information is required by the master? A distinction can be drawn immediately between the information needed by the master when the vessel is underway and that which is required for planning and monitoring of vessel loading/discharging. The underway information is the least developed in both form and content, and includes:

- Seakeeping guidance
  (slam, frequency limits; roll angle limits; interactive effects of wind, waves, power setting, and heading angle; actual stress level monitoring)
- Vessel maneuvering characteristics
  (turning radius; stopping distance; coursekeeping; squat in shallow water)
- Damaged stability information
  (floodable length; damage control)

The second category, operational planning information, includes all information which would be of value to the master and operating personnel in loading the vessel, subject to constraints of draft, trim, stability, and strength.

The "decision variables" for the ship's personnel in loading the vessel primarily involve the amount and distribution of the *deadweight* (i.e. the *variable* loads - cargo, ballast, consumables). Preliminary definition of the range of *feasible* loadings would therefore serve to limit the number and range of stability parameters which need to be checked on board. For example, in a short vessel, bending moment may not be a binding constraint;

it may be impossible for a particular ship to fail in shear; and so on. Satisfaction of the vessel-specific constraints may require operating restrictions (e.g. the vessel's damaged stability requirements may call for certain tanks to be full over particular draft ranges). Ideally, the character and presentation of the operations planning information should reduce the amount of mathematical manipulation (time) required and the potential for errors by the operating personnel, while ensuring a safe loading.

In designing an information system for the safe loading of a ship (be it an electronic aid or a booklet) due consideration should be given to the iterative nature of the load planning and monitoring processes. The initial load plan may result in unsatisfactory trim, stability or stress; loads must then be changed and the condition checked again. For electronic devices, this suggests an interactive mode of operation. In any case, it is desirable to conserve useful earlier calculations. This is of particular importance for containerships which may continue to receive new boxes at the terminal for loading even up to an hour before the ship sails.

However, the range of dry cargo vessels also includes LASH/SEABEE barge-carrying vessels and Ro/Ros. Preplanning of the U.S. loading of these types of vessels is normally done at the operator's principal terminal. The cargo units may be known to the chief officer only as weights designated for specific positions aboard his ship. The operational constraints on the loading process and on the final loaded condition may, on occasion, be imperfectly appreciated by the company planners. Table 4 shows the division of responsibility between various types of ships and the terminal facilities. The calculation

TABLE 4

TYPICAL ASSIGNMENT OF STABILITY RELATED TASKS

VESSEL TYPE	Arrival calculation draft and clearances	Stability - before, during, after loading	Stowage	Order of Operations	Planning of fuel and stores requirements and disposition	Compliance with safety regulations affecting stability during operations	Ballasting - operational or to satisfy stability requirements	Calculated sailing T&S conditions (final)
CONTAINER & RO/RO	S	S + T	T	T	S	N/A	S	S
LASH & SEABEE			S	S				
BREAK BULK CARGO		S						
HEAVY LIFT								
REEFER								
CAR CARRIER								
PASSENGER SHIP								
FERRY: PASSENGER/ CAR								
TANKER						S		
PARCEL TANKER			S or T	S or T			S or T	
OBO			S	S			S	
LNG TANKER								
SLURRY TANKER								
PRODUCT TANKER			S or T					
DRY BULK CARRIER			S			N/A		

S = Ship

T = Terminal

of stability is now taking on additional dimensions of communication difficulties, as terminals and central cargo coordination departments assume more responsibility for cargo stowage. The stow at the foreign terminus may be developed without the ship's inputs, or even without a calculation of the sailing conditions. Planned stows are, in any case, sometimes deranged by circumstances, such as a barge carrier's inability to lift barges overweight due to leaks, or a container vessel's limiting cell and stack weights.

This approaches one of the more severe problems in containership operations, which is the education of terminal personnel in the capabilities and idiosyncracies of particular ships. Of the options available, the distribution of cargo within the ship has the largest effect on drafts, bending moments, and stability. The crew can, at best, react to a bad stow by adjusting ballast or stemming fuel. At worst, the terminal can be requested to remove or restow boxes.

A large factor entering into this problem is that the goal of loading planning is generally only to minimize the use of the container crane, which is coupled with ignorance of cargo to be loaded at subsequent ports on the rotation. It is therefore felt that preparation of guidance material, first to aid in booking cargo for containerships, and second to ensure its technically proper stowage, is of major importance in addressing trim and stability issues in containerships.

Nearly all container companies have damaged their ships structurally through poor stowage by the shore, coupled with inattention or compliance by the crew.

It is desirable to review the changes which have occurred, vessel type by vessel type, before proceeding

to generalize about their actual and hypothetical impacts on the T&S booklet. The interaction between ship changes and changes in ships' cargo operations and configurations has extended and complicated the task of stability assessment in most cases, although it has simplified it in others. The changes in the pace and scale of cargo operations - and consequently in the stability information requirements - of two major types of ships are outlined in the following pages.

1.5 Changing Operational Requirements: Container Vessels

Container vessels, particularly converted vessels, are prone to certain problems in their loading and discharging which are not experienced by general cargo and other vessels.

Excessive list is probably the most significant problem. Alternate lists of 10° or more can be routinely developed during cargo operations when small GMs are often experienced. In many cases, the vessel cannot compensate for more than 7°-8° of list, as her ballast transfer capacity is too small or otherwise restricted. It may also be too slow to keep pace with the changing distribution of containers. There is therefore a possibility that loading may have to be interrupted for container restowing necessary to continue operations, or to permit the vessel to sail. Where crane reach is limited, and the containers must be worked from one side of the vessel only (as in the Canal Zone, for example), this problem necessitates careful preplanning. Frequently, the vessel must sail with offcenter weights, compensated - to the extent possible - by ballast redistribution. Such compensation is limited by the need to meet reserve damage stability criteria, as well as by sailing GM requirements

and, possibly, deadweight restrictions. Container vessels are usually stability-limited in the amount of cargo they can carry.

The increase in length of container vessels, and the size of their hatches, exposes the vessels to higher torsional, shear, and bending stresses. The computation of bending moment and shear force must be performed at the same time as the initial stability calculations, for each operating condition. There is a genuine computational burden in performing these calculations, particularly for large vessels of 3000+ TEUs,* where the stresses may have to be computed at several stations, not merely amidships. The cargo weight information supplied to containerships is usually, but not always, superior to the same information on freighters, with respect to position of VG, weights themselves, and standardization of format. Against this must be set the frequency with which this information appears late in the loading, or is grossly wrong. Errors can accumulate when the actual loading sequence differs from the planned sequence, due to poor sequencing of container arrivals at the crane. There are fewer opportunities for the ship's officers to pick up errors in container cargo data, because container identifications are not readily accessible for visual spot checking.

The results of previous work on stability calculations aboard container vessels are given in Tables 5 and 6 . The errors which were detected in the T&S calculations of these vessels give no grounds for complacency. While the ships sailed with additional GM in 30 instances, in 13 they sailed with excessive bending moment or less GM than stated (not necessarily less than required). The evident

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* See glossary.

TABLE 5 - NATURE OF ERRORS IN CONTAINERSHIPS' TRIM AND STABILITY CALCULATIONS

		Entire Fleet Total 36 voyages
		#/%
1.	Sailed with bending moment in excess of ABS maximum	8 (22)
2.	Sailed with GM in excess of that stated	30 (83)
3.	Sailed with GM less than that stated	5 (14)
4.	Sailed with maximum draft more than 3" different from that stated	17 (47)
5.	Sailed with trim by bow when calculated trim was by stern (or reverse)	1 (3)
6.	Form stated more fuel was in fuel tank than was possible	11 (31)
7.	Weight on permanent ballast on form correct	18 (50)

Source: E. G. Frankel proprietary files.

TABLE 6 - OPERATIONAL CAUSES OF ERRORS IN LOADING CONTAINERSHIPS AND ASSESSING THEIR STABILITY

Loading Plans of Poor Quality

- up to 30% of boxes not stowed according to plan
- cargo loaded immediately prior to sailing sometimes not shown on plan
- limitations on stack weight not always observed
- occasionally shore weights in different units e.g. long tons instead of metric tons - 2% error
- vessels seldom stowed with any real understanding of underlying principles of naval architecture

Little Coordination Between Loading Ports

- cargo from earlier ports usually on bottom even though cargo from subsequent ports heavier
- one port would seldom incur stevedoring expenses to reduce problems at other ports

Vessel and Shore Stability Calculations of Poor Quality

- weights of fluids frequently in cubic meters instead of tons
- arithmetic errors
- weight of permanent ballast incorrectly entered in computations
- vessel's loadicator calculated incorrect bending moment and GM
- hydrostatic properties on capacity plan not the same as in the Trim and Stability Book
- arbitrary free surface correction used which had no relation to vessel's actual condition

Source" E. G. Frankel proprietary files.

frequency of errors in transcribing fuel and ballast figures is disconcerting, and seems to confirm the investigators' impression of difficult circumstances under which stability calculations are made. The errors in draft and trim were substantial and would probably have laid some of the vessels open to fines. The evident difficulty in correctly determining drafts and trim agrees with present respondants' claims that existing trim tables are inaccurate.

Some of the possible operational causes of such common errors in containership T&S calculations are listed in Table 6 . These problems were reduced by computerization of the ship and shore calculations, but several sources of error were misidentified inputs or gaps in officers' basic knowledge. Clearly, there is a real need for further professional knowledge and a higher standard of care and proficiency in performance of stability calculation procedures.

1.6 Changing Operational Requirements: Tank Vessels

Tanker cargo operations are characterized by speed. Standard designs handle 5-10% of their deadweight capacity per hour. This means that cargo handling sequences compatible with requirements for stability and longitudinal strength must be preplanned and continuously monitored, if the vessel is to be stable and trimmed properly at all times and not merely when at the desired sailing condition. In recent years, recognition of the risks involved in tanker operations, and concern for the potential environmental consequences of an accident, has led to the imposition of operational restrictions: for example, it is relatively common for tankers, particularly those with dangerous cargoes, to be required to be able to leave port at any state of the tide without ballasting

or other preparation. This means that the trim, maximum height, draft, and initial stability of the ship must be known at all times. The legislative requirements for continuous monitoring of stability conditions have affected tankers more than any other type of vessel, and in all phases of tanker operations. Ballasting procedures, cargo operations, and tank washing are equally subject to legislation affecting the quantities of liquid retained on board, processed, and discharged.

The volume, number, and carriage requirments of bulk liquid cargoes have increased tremendously in recent decades. Parcel or "drugstore" tankers contend with up to thirty products of different densities and separation requirements, placement of which is governed by IMCO or USCG regulations aimed at minimizing environmental damage in the event of an accident. There is a multiplicity of acceptable arrangements for segregated and protective ballast on crude and parcel tankers. Considerations of commercial secrecy, which often imply shipment under trade names or codes, conflict with the need for details of physical cargo properties such as density to be evaluated in the planning of operations. The presence of residual free surface in the tanks, and the differences in density of the cargo and the dock water, can reduce an initially high GM to a very marginal one.

The parcel tanker in particular has a low freeboard, since the ship is not volume-limited in the amount of cargo it can lift.* The transverse moment of inertia which can be developed on these vessels - which may have no center-

* Segregated ballast requirements may change this eventually.

line bulkhead, and double skins - is large in relation to the vessel. This means that free surface must be continuously monitored.

Despite the trend toward complication of the task of assessing initial stability, the applied problem of longitudinal strength is generally of equal concern to tanker officers, particularly with the increased length of tankers and the return to centerline longitudinal bulkhead construction in certain types of small coasting tankers. Computation of stresses at *several* stations - not merely at the midships point - is a requirement for most modern tankers. Shear force and bending moment caused by empty spaces and tanks - including those designed for carrying protective/segregated ballast or relieving stresses - may require careful evaluation if they are to conform to design limits. In addition, the length, construction, and low freeboard of loaded tankers exposes them to the risk of extensive damage from slamming and shipping heavy seas, and limits their range of stability. Ballasted tankers can select among several patterns of ballast distribution, consistent with tank cleaning requirements. Each pattern affects seakeeping and potential damage stability in a different manner.

2.0 METHOD OF APPROACH

The purpose of this study was to identify and recommend the optimum content and format of stability information for the ship's master and other officers charged with supporting responsibility for calculating the vessel's stability. The underlying objective was to increase vessel safety, by simplifying and speeding up the stability assessment process, and thereby making it more likely to be used as a planning tool rather than a sailing criterion. This identification of the material and formats which could be more easily understood and used by the ship's officer required

(i) estimation of the level of his understanding of stability information presented in trim and stability books and capacity for accurately calculating important stability parameters, particularly GM and righting moments, and bending moments

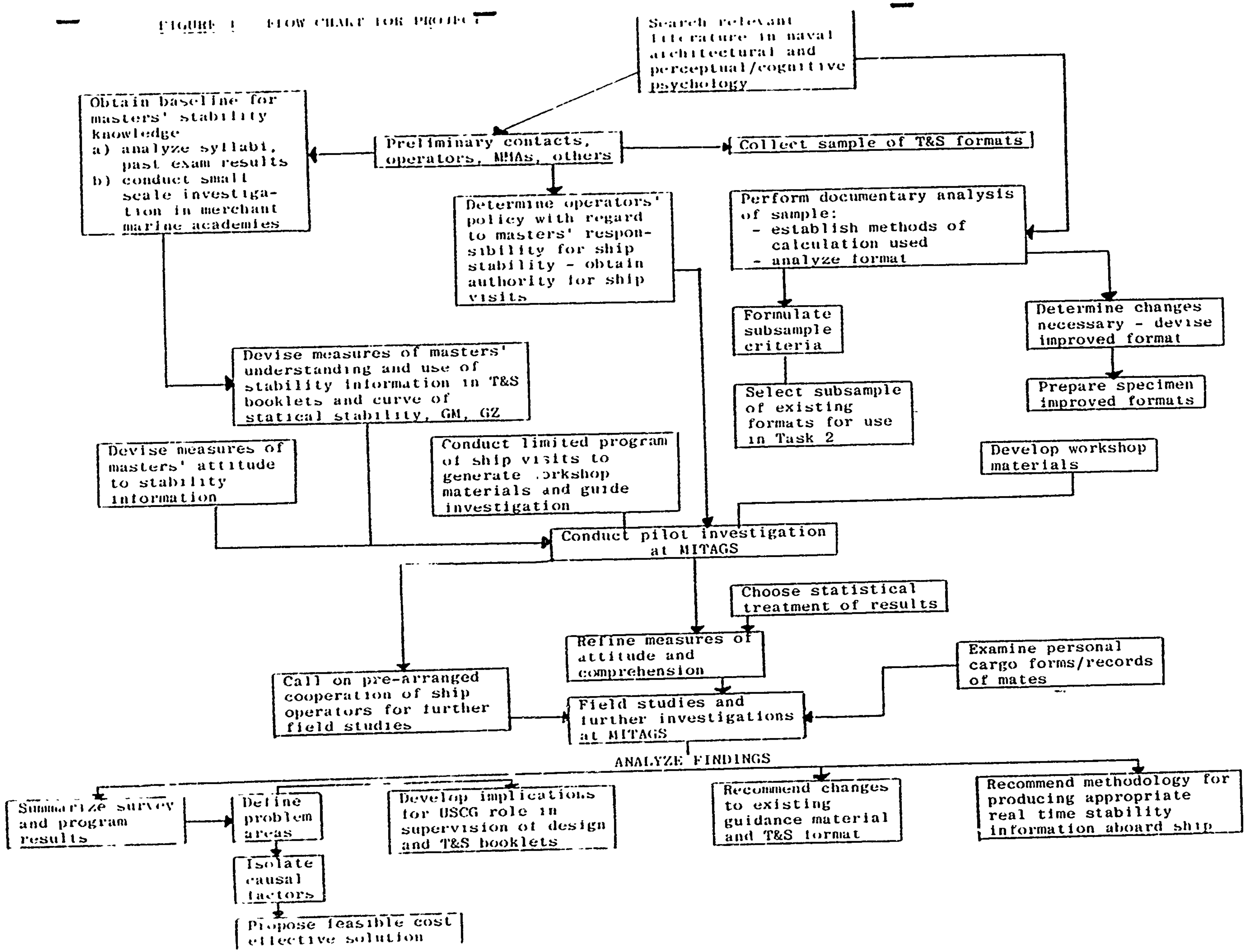
(ii) assessment of his attitude toward the task of stability evaluation

(iii) investigation and analysis of the information presently available to him.

It was postulated that understanding and capacity for application of basic stability principles derived initially from the officer's general level of ability and formal education, while its practical expression was influenced by the attitudes instilled early in training and shipboard service.

Figure 4 shows the actual structure of the study, as it was implemented. Delayed replies are to be expected in a study which requires participants to 'work' at responding, and to expose their operational practices. To compensate partially for this source of delay,

FIGURE 1 FLOW CHART FOR PROJECT



several groups were contacted at the outset of the study. Detailed explanatory letters were sent to training institutions, ship owners/operators, and research/regulatory bodies, in an effort to secure their views and active support. A specimen letter is reproduced in Appendix 1, p 251. While the study was being publicized, a representative selection of USCG-approved T&S booklets was obtained and analyzed (see Table 8). The results of this evaluation constitute Section 4.0. The literature searches were also performed in this first stage of the project.

Shortly thereafter, the responses of the academies and upgrading schools began to arrive. These were followed up by visits and telephone interviews, so that the effects of formal instruction could be assessed.

Subsequently, ship visits were made with operators' cooperation, to explore attitudes and to provide some practical input to the development of suitable materials for a workshop at MITAGS. After the results of the initial workshop - which explored knowledge of stability as well as attitudes - were evaluated, the ship visits were refocused and a second workshop was held to estimate the validity of emergent recommendations. Between the two workshops, an extensive series of visits and telephone calls were made to operators and terminal personnel to establish the views of the industry.

Table 7 summarizes personnel interviewed and the context of where the interview was made. The location of the interview proved to be a significant factor in determining the tenor of the response (see Section 5.0).

The response to the letters announcing and explaining the study was generally cooperative. Even where the objective of the study was disclaimed, some thoughtful

TABLE 7

PERSONS INTERVIEWED

INTERVIEW SUBJECTS \ SETTING OF INTERVIEWS	ABOARD SHIP	MITAGS *	CORPORATE OFFICES	SHIPYARD OFFICES	CONTAINER TERMINAL	LNGC TERMINAL	LASH TERMINAL	PETROLEUM/ CHEMICAL TERMINAL	MMAS **	TELEPHONE	WORKSHOPS	TOTALS
Masters	17	6	1								15	39
Chief Mates/Other Mates	17	3	1								27	48
Terminal Personnel					2	1	1	1				5
Naval Architects			8	3								11
National Cargo Bureau Officers			2									2
Marine Superintendents and Fleet Managers - Vessel Operations			11							4		15
Fleet Managers - Engineering										2		2
Classification Society Officials	1	3										4
Fleet Managers - Recruitment and Training			1									1
MMA - Stability Instructors									2	2		4
MITAGS - Stability Instructors		2										2
MITAGS - Other Personnel		8										8
Other Professionals Connected with Stability	1		3									4

TOTAL 145

* Maritime Institute of Technology & Graduate Studies (Masters, Mates, & Pilots)

** Merchant Marine Academies

TABLE 8

TRIM AND STABILITY/TRIM AND STRENGTH BOOKLETS OBTAINED AND FORMALLY ANALYZED IN THIS STUDY

Container Vessels	2
Product Tankers	4
Tankers	2
Parcel Tankers	3
Segregated Ballast Tankers	2
LNG	3
RO/RO	3
Bulk Carriers	2
Heavy Lift Vessel	1
General Cargo	2
LASH	2
SEABEE	2

comments were made. Since information was obtained under a promise of confidentiality, specific comments and suggestions are not sourced in this report. A distinction will be drawn, however, between general and individual comments and recommendations.

The contacts with ships' officers and others concerned with stability were made in various ways: there have been telephone and personal interviews, exchanges of letters, and observation visits, with or without interviews. Structured, unstructured, and depth interviews have been conducted, within the restrictions laid down by Office of Management and Budget regulations. The principal tools which were used for gathering information about officers' knowledge of stability and requirements for an ideal T&S booklet were ship visits and workshops at MITAGS, the International Organization of Masters, Mates, & Pilots (IOMMP) school near Baltimore.

The purposes of visiting ships, and holding interviews aboard, were two-fold. It was felt that masters and mates would be (i) more aware of the strengths and weaknesses of their booklets and computational methods and aids when these were actually in use and (ii) would be able to comment freely and at greater length. Unstructured depth interviews also provided a basis for structuring the workshop at MITAGS and determining what the consensus and range of officers' opinions were. The general consensus perceived in ship visits was used to spark later discussion.

The ship visits combined observation with unstructured interviewing. The interviews were previously arranged with the respective ship owners/operators. The interviewer was sometimes accompanied on his ship visit by a company or terminal representative, but generally

the interviewer explained the study and conducted the interviews without any comment from the ship owners' representatives. A short, relatively standardized explanation of the objectives of the study was always given immediately on arrival and the interviewer asked the master's personal permission to observe the routine for calculating stability during loading and ask questions of working personnel at appropriate times. Where possible, the interviewer watched the chief officer's complete sequence of routine stability calculations before proceeding to ask general questions of either the master or the chief officer. The rationale of the procedures and the sources of raw data were established during the actual performance of calculations, to minimize unintentional misrepresentation or omissions. When the calculations were finished, and after an examination of the ship's T&S booklet, loading manuals, and other items of stability information, the interviewer asked the senior officers open-ended questions about major aspects of stability assessment. The time allotted to the interviewer, and the range of topics covered, depended upon the situation (e.g. time of day, physical alertness of the officer, and other demands on his time). Where the respondant was both introspective and professionally concerned, these interviews developed into depth interviews in which the respondant was encouraged to relate his training, operational background, and experience to his opinions about the T&S booklet format and contents. Table 9 indicates the main areas in which information was gathered during the discussion/interview portion of each ship visit.

The observational aspect of the ship visit established the location of the T&S booklet(s), their condition, the existence and characteristics of extracted information

TABLE 9

CONCEPTS EXPLORED IN SHIP VISITS

- master's and chief officer's assessments of purpose(s) of the T&S booklet, T&S calculations

- interaction between officers' and operating companies' views of T&S booklets and stability calculations

- type of stability information necessary to satisfy officers' operational requirements (e.g. limiting values of stability parameters, results of specific stability calculations):
    - before agreeing to accept the prestow
    - before sailing
    - during sea passages

- sources of stability problems experienced by the respondant

and manner in which it was employed, and other factual matters which entered the evaluation of the interview and the officers' opinions. Wherever possible, the visit included observation of a complete cycle of stability calculations and acquisition of copies of the ship's/ mate's own forms for computing and recording stability, trim, and longitudinal strength.

A wide range of vessel types (Table 10) was visited in order to assess the degree to which vessels' requirements for stability information differed. Similarly, the interviews held at MITAGS included a broad range of seafaring backgrounds. The recommendations of 6.0 are therefore broadly based, though necessarily subjectively derived.

The two workshops differed in their approach. Both began by establishing some measure of participants' conceptual understanding of basic stability concepts. Workshop #1 went on to develop a discussion centered on evaluation of alternative presentations, and a component-by-component review of the utility of the booklet, while workshop #2 was divided between a survey of attitudes toward tentative recommendations, expressed as items on a Likert scale, and a free discussion of a particular T&S calculation format which incorporated many features which were thought to be desirable.

The first workshop was monitored by two of the project staff, who were joined by a third in the second workshop. This enabled the results to be followed without obtrusive note-taking and facilitated alternation between general and small-group discussions as the focus of interest became general or vessel/trade specific. MITAGS made available a choice of areas, but the "break area" was felt to be the most relaxed. Each workshop

TABLE 10 VESSEL TYPES VISITED FOR THIS STUDY

(N = 17)

Dry Cargo Ships

- General Cargo
- Bulker
- LASH
- SEABEE
- Containership
- Heavy Lift

Tankships

- Parcel
- Crude
- Clean Oil
- Dirty Oil

LNGC

RO/RO

TABLE 11 - CONCEPTUAL UNDERSTANDING OF STABILITY: WORKSHOP MATERIALS STRUCTURE

MITAGS 1

- collection of biographical data
- IOMMP-sponsored examination of officers' understanding of stability
- depth interview (function: generation of ideas, critical incident exploration
- workshop discussions

  Topics explored:

  - participants' training and comfort with various presentations of ideas
  - ship/shore relations in cargo operations, data transmission
  - chief officer-master relations in stability assessment process
  - extent and awareness of sources of stability information aboard ship
  - attitudes to task of assessing stability
  - centrality of stability assessment to seakeeping effort

MITAGS 2

- opinion survey
- format evaluation
- workshop discussions

  Topics explored:

  - function of T&S booklet
  - desired format of T&S booklet
  - desired content of T&S booklet
  - desired information not presently furnished

began with a standardized explanation of the study, an assurance of confidentiality, and a willingness to answer any questions the participants might have.

The workshops consisted of two 1 1/2-hour sessions each, beginning at 16.00, after classes. Each was followed by interviews during the evening and a range of informal contacts between the project staff and the students at MITAGS. There was a break between the sections dealing with stability knowledge and opinions of booklets, in each case, and the staff moved around in the "break" area so that an informal, highly personal atmosphere developed. It was necessary to draw a few of the respondants out: some officers tended to feel they had little to contribute, because they used electronic alternatives to the booklet almost exclusively. Allowing time for the participants to examine the selection of exerpts from booklets helped to overcome this feeling. Officers who wished to leave were able to leave without embarrassment, because of the arrangement of the "break" area and the physical movement of the investigators. The loss of participants was much smaller than expected. On the whole, the cooperation was impressive. The effort made by participants to give reasoned, clear explanations of their opinions lends weight to the workshop results.

Though the evening interviews with masters used the instruments developed for shipboard use, they were longer and wider ranging than those shipboard interviews. The sources and development of respondants' professional attitudes to stability was a major focus. Many had academy and/or other formal training, followed by an intensive course in stability at MITAGS. These respondants volunteered their opinions about the effects of training on practical management of vessel stability, which helped the project staff in formulating overall conclusions about

training effects.

The informal contacts were unsystematic, but accumulated useful impressions and requests were made for specific types of presentations and information.

The materials used during the two workshops are reproduced in Appendix 1, pp. 256-328, and the statistical evaluations in Appendix 2. The appropriate level of statistical treatment was restricted by the sample size, and the biases arising from the fact that the sample was both volunteer and affected by seasonal attendance at MITAGS. The exploration of conceptual understanding of stability drew on the analysis of existing booklets and the conclusions of the previously discussed 1979 study of containership T&S booklets. Table 11 summarizes the workshop procedure and the functions of the various instruments. Although the contractor would have anticipated interesting results from displaying materials developed by professional graphic designers, and commercially-produced, this would not have been cost-effective.

3.0 TRAINING AND LICENSING REQUIREMENTS: EFFECTS ON COMPETENCE IN USE OF STABILITY AIDS

All ship's officers have received *some* formal training in the principles and calculations of stability, together with informal training in the professional attitudes and methods of their mentors. Some of this composite training may be twenty years old and overlaid by successive upgrading and short professional courses. Officers are probably not consciously aware of the ideas and attitudes about stability which shape their approach to new problems. The importance of training derives from two facts: first, it can induce a mental 'set' which channels and perhaps constrains the officers' capacity to adapt to new requirements for complex, real-time stability information and calculations; second, the attitudes which were developed during the training are implicitly perpetuated, as each new group of graduates is absorbed into the maritime community and taught its customs and values.

Unfortunately, only the undergraduate education can be easily evaluated. No statistics are published of attendance at upgrading and union schools, nor is initial testing emphasized at these institutions, when generally have an open admissions policy. Indeed there is no definitive profile of the training and development of the merchant marine officer readily available. The records of the House Committee on Merchant Marine and Fisheries contain much recent and authoritative material, but it is somewhat polemically presented and requires analysis outside the scope of this investigation. One potential source of information about training - the application for license examination - asks the indivdual about his training *immediately preceding* the examination. Hence

development of a career profile would require each officer's successive applications to be pulled and his educational and employment history taken from them. This will be possible within the near future, when the files of the Coast Guard Institute are put on magnetic tape and the programs for interrogating their computer are written.

The investigation of the academies' perception and endorsement of stability principles and techniques was therefore both a preliminary to, and a tool for, the development and implementation of improved T&S formats and techniques of calculation. In addition to its intrinsic value, such an examination of the context and objective of initial stability instruction was necessary to develop new formats and methods of calculation which build on earlier training and therefore can be fully understood, and extended as necessary.

The effect of formal and informal training on officers' attitudes toward stability information, and the level of competence attained, is assumed to be mediated by at least two classes of factors: individual characteristics such as general ability, social sensitivity, and specific aptitudes, and the structure of the course in training - the integration of practice and theory, the length of exposure to each topic, the extent of supportive feedback concerning performance, etc.

The recent oversight report on the Federal role in marine education determined that the general level of ability of academy entrants, as expressed by national test scores and high school academic performance, had risen in recent years. See Appendix 4 (p 352). This statistical evidence was confirmed by the instructors of the various academies. Candidates' performance was well above national average, and this is one of the

bases on which the contractor feels able to recommend including additional material such as cross curves in the T&S booklet.

The second mediating factor, the structure of training, is directly affected by USCG licensing regulations: firstly by the need to ensure that training and license requirements coincide and secondly by the intensive pre-examination courses in license examination content. Sections 3.1 and 3.2 are not attempts to catalogue the characteristics of an appropriate stability syllabus and successful stability training program, bit rather a review of training and license requirements and an inventory of U.S. maritime academy programs in terms of the attitudes and skills they teach.

Implementation of the results of this study would ideally require the cooperation of the training institutions in revising or developing cost-effective training programs which reflect changes in the content and format of trim and stability/strength booklets.

3.1 Institutional Definition of Stability Knowledge: Professional Examinations and Stability Knowledge

Before becoming a licensed deck officer, a graduate (or an able-bodied seaman who has logged 3 years of sea-time) must sit and pass the Coast Guard licensing examination. This examination reflects some very general international guidelines, but its specific content is determined by the Coast Guard Institute in Oklahoma. Applicable international conventions are discussed in Appendix 4 (p 348). Table 12 reproduces the stability syllabus, which affects principally senior certificates.

A candidate for an original license must pass in each of six examination sections. If he fails one or two of the six sections, he may retake the failed sections within

TABLE 12

STABILITY SYLLABI, MASTERS' AND CHIEF OFFICERS' LICENSE EXAMINATION *

		Chief Mate	Master
C.	Stability and Ship's Construction		
1.	Calculation of Metacentric Height	X	X
2.	Calculation of KM	X	X
3.	Inclining Experiment	X	X
4.	Stability at Large Angles of Inclination	X	X
5.	Free Surface	X	X
6.	Damage Stability	X	X
7.	Trim and List	X	X
8.	Stability and Trim Computers and Tables	X	X
9.	Practical Stability and Trim Conditions	X	X
10.	Hull Construction, Stresses and Strain, Cracks and Temp. Repairs, Ballasting	X	X
11.	Structure	X	X
12.	Watertight Doors and Escape Ports	X	X
13.	Shipbuilding Terms and Abbreviations	X	X
14.	Inspection of Repairs and Alterations	X	X
15.	Dry-Docking	X	X
16.	Vessel Maintenance and Upkeep	X	X
17.	Stabilizer Systems such as Flume Systems	X	X
D.	Vessel Damage Control		
1.	Assumed Conditions	X	X
2.	Damage Results and Controls	X	X
3.	Jettisoning of Cargo		
4.	Wind Heel	X	X
5.	Damage control Check Off list	X	X
6.	Flooding, Wt. Bulkheads, Subdivision, Means of Escape From Compartments, Control of Watertight and Fire Screen Doors	X	X

*Source: Specimen Examinastion for Merchant Marine Deck Officers (Master and Chief Mate) Ocean, 1978, CG-101-2.

the next 3 months. A candidate who fails more than the permitted number of sections on the initial examination, or who fails any section on the first retest, has failed outright and must retake the entire examination.

Although data on performance of persons from various sources (hawsepipe, academies, union schools) on Coast Guard licensing examinations is compiled and published by the Coast Guard for each calendar year, this data is not normally broken down to show the performance of examinees coming from a particular school, and in addition, the statistics refer to the number of of examinations and reexaminations rather than the number of examinees.

The stability content of the U.S. Coast Guard license examination, which is given in Table 12, is based upon LaDage's book, Stability & Trim, insofar as it draws on any specific book. The examination, which is under continuous revision, is developed primarily by staff of the Coast Guard Institute. There is provision for participation of the profession: questions may be freely submitted for review and possible inclusion in the exam. Stability topics are covered primarily in the chief officer's examination syllabus. Only the basic concepts, such as the importance of VCG, appear in the lower licenses. This reflects the accepted distribution of responsibilities aboard ship, as well as the lack of prescribed training in stability, apart from (optional) attendance at a merchant marine academy.

The change from an essay form of examination, supported by an oral, to a machine-scored multiple choice was (and is) controversial. In discussing the coverage and effect of the change with stability instructors and various marine professionals, the apparent consensus was

that the change diminished the test coverage of stability understanding. There are very few questions devoted to stability in an average masters' license examination. Stability is in the section, "Deck-General", Part B. Pass mark is 70%. This section has a total of fifty questions, perhaps four of which relate directly to stability. Judging by CG-101-2 and the examination handbooks published by Cornell Maritime Press, the Blue Book and the Study Guide, the major emphasis is on calculation of GM and the effects of operations on GM (virtual loss of, effect of transverse shift of G on, etc.). Practical questions on effect of changing water density on draft, fresh water allowance, and use of anti-rolling devices are also included. There is no attempt made to score stability competence separately, nor could such an attempt be meaningful given the small number of stability questions routinely included. It would be instructive if the Coast Guard Institute reviewed these impressions, and performed the item analyses to quantify the extent of understanding of stability concepts in the examinee population.

3.2 Stability Syllabi at Merchant Marine Academies

Initial instruction in stability assessment is considered an important matter of eventual performance, even if further formal instruction is received during license upgrading. Accordingly, the stability syllabi in schools and licensing bodies were examined to provide some background for the study. Estimation of the extent to which the desired result - competence in stability assessment - was achieved was one of the principal objectives of the inquiries at MITAGS.

The colleges which responded to notification of the project included California Maritime Academy, Massachusetts

Maritime Academy, Maine Maritime Academy, Moody College (Texas A&M), and Northwestern Michigan College. In addition, several private schools and textbook publishers cooperated. These institutions provided catalogues, course outlines, reading lists, and in some cases specimen instructional material to indicate the type of approach they were attempting to instill. Since high staff turnover is a feature of most of these institutions, student performance data are not comparable for successive years. No institutional time is allowed for staff to analyze and statistically describe students' performance in internal and license exams, although many wish to do so.* Two respondants indicated that there had been an upward trend in internal examination performance over the past five years, but one dismissed this as a statistical artefact, a false impression resulting from inflation of the grading system.

Instructor's comments on the courses were more illuminating. They discussed the difficulties of presenting a mathematical subject to classes with varying levels of mathematical proficiency, the time limitation on stability instruction, and other aspects of the problem. Their views were generally offered as personal impressions but indicated a range of problems which have serious implications for individual success in mastering the stability syllabus.

Appendix 4 p 356 reproduces the catalogue's thumbnail sketches of naval architecture and stability courses at

* This is evidently not the case in the union schools, where student/staff ratios are lower and more use is made of feedback of various types. The IOMMP school in Baltimore, the Maritime Institute of Technology and Graduate Studies, provided a complete set of instructional materials and a detailed explanation of the union school training philosophy.

several merchant marine academies. It is evident that the initial course is largely devoted to learning the vocabulary and underlying principles of naval architecture. The second course attempts to teach basic operational principles of stability and trim. Specific problems facing operators of tankships, barge carriers, container ships, and other specialized vessels are reserved to transport management courses or left for the student to explore during sea service. Only one academy used T&S materials from a modern vessel in its course work.

The influence of LaDage is very evident in some merchant marine academy syllabi (see Appendix 4, p 356). Routine use of additional texts is not common. Most stability courses cover a large syllabus and must devote a proportion of their time to learning and practicing computational routines. Stability courses make high demands on students' study time: the courses range from 30-56 hours in length and the average reading and the homework burden is 45-84 hours in addition to this. The student has only 75-140 hours, in total, to understand the basics of trim and stability and learn the computations. This precludes the use of several references to explore the basis, assumptions, and implications of the central concepts. When pressed, instructors indicated that texts such as Derrett, Gilmore, and Baker were suggested for additional study if particular topics proved difficult for an individual.

As previously noted, the text most commonly used in the maritime academies - LaDage and Van Gemert, Stability and Trim for the Ship's Officers (2nd edition, 1972 reprint, Cornell Maritime Press) - is also the basis of the license examinations. This book is in the process of revision, but most serving senior officers have been exposed to one

or other older editions of it during their normal training. These might better be termed reprints than editions, because they reflect none of the postwar changes in vessel design and operations. The book's treatment and contents are of significance in highlighting (i) the relatively theoretical and naval architectural orientation of many texts used in formal instruction, and (ii) the polarity between perceived CG license requirements for stability knowledge and the practical requirements for stability knowledge to secure vessel safety and optimal seakeeping.

The most successful academy courses (in terms of graduates' favorable attitudes and apparent skill) shared several characteristics. There was less direct keying of instruction to a text. Operationally relevant principles were emphasized, and there was an awareness of the intimidating effects of the naval technical vocabulary. Coverage was curtailed to match the time available, so that there was a firm basis for follow-on self-instruction. Direct instruction in licensing requirements was separated from the designed stability curriculum.

3.3 Institutional Effects on Officers' Attitudes and Competence

Three powerful institutions affect the real and legally-defined competence of the merchant marine officer. The Coast Guard sets the license examination syllabus, the colleges and upgrading schools teach a syllabus which reflects the license requirements, and the naval architectural profession provides the vehicles and T&S booklets with which the officer works in practice. There is sufficient divergence of aims and methods to confuse the ship's officer.

The perceived requirements of the license examination tend to define orthodox opinions about stability, and also

exert a powerful influence on the teaching of stability. This is due partly to the fact that the pass rate is a generally accepted criterion of the school's success in fulfilling its educational objectives. The license examination's influence is naturally exerted toward securing competence in assessing stability *by the accepted criterion* - viz. GM. The desire to produce graduates able to obtain the 3rd mate's license is one reason which has led many of the colleges to adopt LaDage, the book which underlies the license exam, as their text on ship stability despite its age and serious shortcomings, prime among which is its emphasis on GM and undervaluation of other indicators of stability.

The prestige and specialized training of the naval architectural profession also affect the teaching of stability, which is almost always approached by way of a necessarily superficial course in naval architecture. The question is raised for general consideration, of whether a single course based upon laboratory exploration of concepts underlying stability might not be possible and more effective, even given the time constraints and limited science lab facilities on most MMA campuses. Traditional approaches seem to rule unquestioned in the teaching of stability, despite the efforts of individual instructors. Naval architecture could be studied later by those interested, in the detail it merits, and in the meantime a general glossary can assist with the admitted vocabulary problem.

The existing stability course, shaped as they are by license requirements, traditional influences, and very real constraints of time and funding, are not promoting "good" attitudes toward stability. They are teaching over-reliance on GM and are not fostering the ability to perceive emerging new problems in safe vessel operation. The problem can be effectively examined by reviewing

stability texts, because these are so tightly tied to the teaching (see the page by page tie-in of text and course in the specimens in Appendix 4). Because this problem is so central to the issue of what *can* be included in the T&S booklet, it is appropriate to devote space here to a review of LaDage and other texts in terms of their suitability and their interaction with the perceived traditionalism which has already been mentioned.

LaDage is the primary text addressed, because it is the most widely used. Its shortcomings are not unique. Nearly all texts examined for the study employed a similar approach. They devote much space to topics such as KB, and the inclining experiment, which are operational irrelevancies. On the other hand, they ignore the need to teach computational methods based on actual practice and suited to ships' present equipment and circumstances. The contents of several important texts, including Walsh's modern treatment of container and barge-carrying vessels, are tabulated in Table 13. Macy's text, developed for Sea Land, was chosen because it was developed in a long-term effort to help one operator's personnel understand a very new and complex class of vessel. Derrett is a British text whose preeminence compares with LaDage, and which is referred to by several of the U.S. instructors. The Study Guide and The Blue Book were added because of their importance in revision for the license examination. Table 13 will help to keep the subsequent discussion clear.

LaDage's text, like many stability courses, begins with a discussion of some underlying naval architectural principles. These could equally well be addressed by a physics text, or at least in more general terms, so that they would assist the student to understand the simple machines used by deck personnel. The criticism which we are making here is essentially that a professional

TABLE 13

TABULATION OF CONTENTS OF STANDARD STABILITY TEXTS AGAINST LADAGE

	Sealand Vessel	Naval Architecture	Derrett	Study Guide	Blue Book	Walsh
WHAT IS STABILITY?						
Definition						✓
Centers of gravity and buoyancy	✓		✓	✓		✓
The couple						✓
Righting moment and righting arm	✓			✓		✓
Initial stability	✓		✓	✓		✓
Transverse metacenter	✓		✓			✓
Stable, neutral, and unstable equilibrium			✓	✓		✓
Metacentric radius	✓		✓			✓
Summary						
Questions						
CALCULATION OF METACENTRIC HEIGHT (GM)	✓		✓	✓		✓
Center of gravity in the light condition			✓	✓		✓
Using moments to find KG			✓	✓		
The calculation of GG'	✓		✓	✓		
Procedure for finding VCG when loading or discharging vessel	✓		✓			
Finding center of gravity of compartment			✓		✓	✓
Stability versus stowage						
Relation of metacentric height to rolling period	✓		✓	✓		✓
Natural, forced, and synchronous rolling	✓		✓			✓
Proportionate loss of stability						
Rolling period for different types of vessels	✓		✓			✓
Effect of negative GM on vessels			✓			
Correction of list			✓			
Form for calculation of GM						
Sample problems						
Questions and problems						
THE CALCULATION OF KM			✓	✓		✓
What is KM?						
The calculation of KB	✓		✓			✓
Analysis of approximate formulas for KB			✓			✓
Calculation of BM	✓		✓			✓
Moment of inertia	✓		✓			✓
Importance of beam						
Approximation to BM for curved water planes						
Analysis of vertical movement of transverse metacenter	✓					
The effect of beam-draft ratio on vertical movement of M	✓					
Summation of vertical movement of M						
Movement of M with transverse inclination						
The metacenter in a circular section						

TABLE 13

(continued)

	Sealand Vessel Naval Architecture	Derrett	Study Guide	Blue Book	Walsh
Questions and problems					
THE INCLINING EXPERIMENT					
The problem of light *KG*		✓	✓		✓
Light *KG*'s for various Maritime Commission vessels		✓	✓		✓
What is the inclining experiment?					
Required gear and data for the inclining experiment					
Performing the inclining experiment		✓			
To find the deflection of pendulum		✓			
Derivation of the inclining experiment formula		✓			
Precautions to be taken during the experiment					
Example of an inclining experiment				✓	
Ordering the inclining weight			✓		
List problems using inclining experiment formula					
Legal requirements relating to the inclining experiment		✓			
Questions and problems					
STABILITY AT LARGE ANGLES OF INCLINATION					
The construction of cross curves of stability	✓	✓	✓	✓	✓
Drawing the statical stability curve	✓	✓			✓
Correcting the stability curve for a change in displacement	✓	✓			
Correcting the stability curve for a transverse shift of *G*	✓		✓	✓	✓
Analyzing a statical stability curve	✓	✓	✓		
Initial slope of the curve	✓	✓			
Angle of inclination of maximum righting arm	✓	✓			✓
Angle of maximum list	✓	✓	✓		
Value of the maximum righting arm	✓	✓			
Range of stability	✓	✓			
Dynamical stability	✓	✓			
Over-all stability characteristics	✓	✓			
List caused by negative *GM*	✓	✓			
List caused by *G* being off the center line	✓	✓	✓		
List caused by combination of negative *GM* and *G* off the center line	✓	✓			
Questions and problems	✓				
FREE SURFACE			✓	✓	
Effect of surface dimensions on free surface	✓	✓			
Effect of specific gravity of liquid in vessel	✓	✓			
Effect of depth of liquid in tank					
The effect of the weight and vertical position of liquids on transverse stability	✓	✓			✓
Table of free surface corrections	✓	✓			

TABLE 13

(continued)

	Sealand Vessel	Naval Architecture	Derrett	Study Guide	Blue Book	Walsh
Free surface constants				✓		
The cross-connection valve for deep tanks				✓		✓
Effect of free surface on over-all stability	✓		✓			✓
Questions and problems						
DAMAGE STABILITY						
Lost buoyancy method	✓		✓	✓		✓
Intact buoyancy			✓			✓
Surface permeability	✓					
Added weight method	✓		✓	✓		✓
The dangerous effect on stability of flooded wing compartments			✓			
The effect of grounding on stability			✓			✓
The effect of flooding on reserve buoyancy	✓		✓			
What is floodable length?				✓		✓
Permeability			✓			✓
What is the factor of subdivision?						✓
How the ship's officer uses floodable length curves				✓	✓	✓
Effect of permeability on floodable length				✓	✓	✓
How fast will a ship sink?						
Questions and problems						
TRIM						
Trim definitions	✓		✓			✓
Change of trim	✓		✓	✓		✓
Trimming moments and moment to change trim one inch	✓		✓	✓		✓
Longitudinal stability	✓		✓			✓
MT1 formulas	✓		✓			✓
To find where weight may be loaded to change draft at one end only			✓			✓
Effect on displacement readings due to trim				✓		✓
Effect of trim on transverse stability	✓					✓
Effect on trim of passing from salt to fresh water			✓			
Effect of trim on draft readings	✓		✓			
Change of trim due to large weights loaded or discharged	✓		✓			
The *LCG* method of trim calculation	✓					
Examples of trim problems			✓			
Questions and problems						
STABILITY AND TRIM COMPUTERS AND TABLES			✓	✓		
The stabilogauge						
The Trimogage						
The Ralston stability and trim indicator			✓			

TABLE 13

(continued)

	Sealand Vessel Naval Architecture	Derrett	Study Guide	Blue Book	Walsh
Table of stability					
Trimming tables					
Trimming graphs					
The Marcom Stability Book					
The Mariner Class Trim and Stability Booklets					
PRACTICAL STABILITY AND TRIM CONSIDERATIONS					✓
Factors affecting the rolling of ships	✓			✓	✓
Effect of GM on rolling	✓		✓		✓
Effect of draft and displacement on rolling					
Effect of mass moment of inertia on rolling					
Effect of synchronization on rolling			✓		
Effect of antirolling devices on rolling			✓	✓	
What is a good GM?		✓			✓
Ballasting		✓	✓		✓
How small a GM can we employ with safety?					✓
How to load a ship to obtain desired GM and trim					✓
Simplifying the use of stability curves					
MARINE DISASTERS DUE TO LOSS OF TRANSVERSE STABILITY					
The *Samkey* disaster					
The *Mormackite* disaster					
The *Flying Enterprise* disaster					
BIBLIOGRAPHY					
APPENDIX					
Center of gravity computer					
Typical questions and problems on stability and trim		✓			
Glossary of stability and trim terms		✓			✓
Hydrostatic Curves, Victory ship					
Useful stability and trim formulas		✓			
Formula for BM derived					
KM table for Maritime Commission vessels					
Capacity Plan					
Table of VCG's — Maritime Commission vessels					
Mathematical tables					
INDEX					

orientation - less useful than a more basic, familiar approach - is being instilled, to the detriment of the student, whose ability to perceive general principles is not being fostered. Training the ability to apply scholastic knowledge to the interpretation of experience is one of the basic functions of instruction. Most of the formal stability courses and texts can be faulted for teaching a overspecialized approach which does not advance, and may even undermine, this ability to progressively build knowledge.

Chapter 2 of LaDage deals immediately with GM, which establishes the centrality of the concept in the user's mind. Ample evidence was found at MITAGS that this concept is felt to imply more than it does and can. The warnings in LaDage - "...stability at large angles of heel as well as initial stability must be the object of routine concern[1]" - evidently do not reverse the effect of the early prominence of GM in the text.

A major criticism, that the book discounts the actual experience and needs of seafarers, is directly related to this overemphasis of initial stability. The full range of stability information is increasingly needed, not least because ships do in fact encounter sea conditions where large rolls occur not sporadically but for hours on end. It is not true to say that "...transverse inclinations greater than, say, 20 degrees very rarely occur."[2] Furthermore, the concern of the seafarer could be for a unit which includes both a ship and an almost equal volume of deck cargo - the vessel characteristics are no longer the sole concern. The ship's master wishes to know his stability in relation to such quantities as the strain placed on his cargo lashings, as well as to assure

[1] LaDage, p. 61

[2] LaDage, p. 61

himself that he is handling his vessel correctly and that it is capable of withstanding the sea conditions.

The discussion of KM and the inclining experiment do not seem worthwhile in light of the limited time available for stability. Note that Macy does not bother with anything more than the minimum needed to make his subsequent discussion intelligible. These topics are certainly not license-related.

Stability at large angles of inclination is actually treated less thoroughly than appears from the tabulation. The mechanics of the cross and static stability curves are treated in more detail than their interpretation. (This was not true of the materials supplied by MITAGS.) The T&S booklet is perhaps the best place for guidance on the statical stability curve interpretation, since there it can be directly related to the structure of the vessel.

Adequate treatment of the flume tanks is not found in standard stability texts, although free surface is dealt with clearly and in sufficient detail. This is discussed elsewhere in this Report. Operation of the flume tanks in the damaged condition should be considered, which leads to another major topic, damage stability.

It is disconcerting to note that floodable length curves are prominently treated, although seafarers do not understand these, or have them available to use. The discussion of parallel methods of assessing final flooded conditions seems gratuitously difficult, and altogether, a simple treatment of this topic would be desirable. The damage stability book developed by Macy is one such possible treatment, practically oriented, and favorably evaluated by users.

Trim is a matter of operational concern to seafarers, and is given a highly theoretical treatment. The practical use of trim tables, Van Der Ham diagrams, Koehler slide

rules, and electronic aids is not related to the theoretical treatment. New vessel forms which must use an LCF draft in trim computations are not acknowledged nor are the limitations on the validity of conventional hydrostatic tables, which are based on an even-keel assumption. The subsequent treatment of T&S aids is historical and does not deal with the sources and evaluation of inaccuracies, which are common and substantial.

These problems in texts and courses make it less probable that the new graduate will have a desire to teach himself about the stability and behavior of his new ship, and they do not make him aware of the need to consider strength at the same time. By appearing to separate stability from other physical phenomena, they handicap his observational insights. This unfortunate state of affairs is reinforced by the format and approaches of the T&S booklets themselves.

T&S booklets are usually provided in only two copies, of flimsy character, which discourages masters from giving copies to the cadets and junior officers. Their development by naval architects or other shore-based professionals is reflected in a limited operational usefulness. The booklet designers' concern for the increasing complexity facing the ship's officer expresses itself in a lengthening of the booklet, which militates against the requirement for *quick* methods of stability assessment. The attitude and message being conveyed in stability texts opposes increased capacity to make flexible use of a stripped-down T&S booklet. A major exception to this is W. Michael Walsh's <u>Trim and Stability Guide for Container and Barge-Carrying Ships</u>, which adopts a two-pronged approach. Relevant naval architectural principles are reviewed from an operational viewpoint, before direct exposition of how to use the T&S

booklet. The questions following each section of text are most valuable to the officer studying on his own: they are instructive in themselves, and build confidence in using the booklet rather than bowdlerized calculation forms.

3.4 Conclusions on the Functionality of Formal Stability Instruction

There appears to be little difference in knowledge of stability at the level of chief mate and master, whether much formal instruction was received or not. Academy syllabi have been rendered very similar by the forces discussed in 3.3, and the lack of funds for laboratory facilities and audiovisual aids. There is no institutionalized means of guiding the practical acquisition of stability and strength knowledge during sea experience, initial and/or subsequent. Peer influence is the principal factor in shaping and perpetuating approaches to the judgment of stability and vessel handling.

This leads to the conclusion that the potential value of formal instruction is not being realized. Several causes for this can be identified. The instruction is not responsive to practical needs, and does not train powers of observation. No text is available which covers the appropriate material in a useful treatment. There is no follow-up by correspondance courses or guided study.

The capable performance of officers who have come up through the ranks indicates that there is untapped potential in the marine community's self-instruction resources. Serious consideration needs to be given to the provision of teaching aids - videocasette television, for example - which encourage and facilitate learning on the job. The assistance of the existing library and service agencies could be enlisted in scoping and

implementing efforts along these lines.

The attitude toward stability which results from the formal and subsequent informal training is one of limited usefulness. Stability includes strength assessment and therefore is not merely a computation of transverse stability (GM). It is a tool for use in preplanning and operations surveillance, as opposed to a legal, presailing criterion to be met. When regarded as part of a systematized on-going documentation effort, like logs and cargo reports, it need not be onerous. The changes which should be fostered in attitudes, through training changes and supportive facilities during the voyage, are further discussed in Section 7.

4.0 REVIEW AND EVALUATION OF EXISTING T&S BOOKLETS

In this section, the contents and presentations of typical T&S booklets are reviewed and evaluated. The relevant dimensions of content, format, and compatibility are considered listed in Table 14, together with some of the considerations, parameters, techniques, etc. which govern the review.

The evaluation of the congruence of content and format with master's requirements was based on the legal and operational requirements outlined in Sections 1.3 and 1.4, and the perceptual considerations discussed in Appendix 3, p 336. The preparation of T&S booklets involves significant expense in absolute terms, though the booklet is a tiny fraction of the total bill. More important, the compilation of irrelevant information alienates the ships' officers. Does the master's need justify the provision of each item of the booklet? Most booklets contain inconsequential information which should be eliminated. There is a certain common superfluity arising from separation of tables which could be combined. Conversely, there is the question of optimal content. Additional useful information and alternative presentations of information can be secured at a very low cost *at the time of compilation of the booklet*. What should be supplied? This is a question of personal values and views of ships' officers, and a key issue in merchant marine operating philosophy. This will be raised in Sections 6.0 and 7.0.

Format was evaluated with respect to perceptual and cognitive ease. Perceptual ease is largely a function of known factors, which govern visual perception as described in Appendix 3. This rather mechanical review becomes a judgment of cognitive issues (i.e. comprehensibility) as the problem of designing a format supportive of the logic

TABLE 14 TRIM AND STABILITY BOOKLET: EVALUATION CHECKLIST

Dimension	General Problem	Consideration and Objectives	Parameters, Criteria, and Techniques of Investigatio
Minimal Content	Does the master's need justify the provision of each item of the booklet?	Is it worth the expense of preparation and the complication of use?	Cost-effectiveness studies
		Can the master manage as well, or better, without it?	Justification other than on grounds of information: tradition, flexibility, comprehensive uses
		What happens if it is misinterpreted or simplistically interpreted?	Critical incident studies. Possibilities: conventiona stability assessments present inadequate information or present false information
Optimal Content	What data may the master need which have not been provided?	Would more data be useful to set up or change stability conditions? in case of problem? about past state? present state? future state?	Hardware optimization; Task analysis
			Should T&S material (incl. electronic aids) graduall incorporate historic data, quickened displays, predictor displays
Format	Can an operator with average intelligence and visual acuity use the format to produce what is required?	Are unnecessary entries or cross references required to extract the data?	Experimental designs - especially search tasks. Corrections, interpolations, and unnecessar entries may: take more time, involve more concentration or effort, involve change of source/format, expose user to error

TABLE 14 (continued)

Dimension	General Problem	Consideration and Objectives	Parameter, Criteria, and Techniques of Investigation
		Is the presentation optimal?	Visual parameters: position, size, orientation, lettering size style (e.g. use of serif vs. sans serif typeface)
		Is the signal-noise ratio high enough?	Visual parameters of format: contrast, freedom from fading, running of figures, glare
		Is it clear where the data are available? Is it clear when the presented data apply?	Connections with real events: physical, symbolic, legends
		Have unnecessary data been eliminated? Is the accuracy appropriate in terms of: hardware used? perception?	Error summation studies
Compatibility	Does stability outfit conform: to the real world		
	with previous habits and skills	Will the master require special training?	Skills analysis
		Is there likely to be a discontinuity with the master's experience?	
	with required decisions and actions	Does the presentation encourage the master to: think about the right problem in the right way? select the right action and move in the right direction?	Must be capable of being encoded to match perceptual models Calculation-procedure relationship: tool vs final criterion

of the booklet is faced. In this area, the estimated levels of users' reading and mathematical skills were compared with those implied by existing formats.

The dimension of compatibility is closely allied to the cognitive soundness of format. If the stability related materials draw on real examples, and embody the practices the user knows and feels confident of, then the likelihood of successful use of the materials is vastly increased. Most users will have an innate desire for consistent treatment of the trim/stability/strength problem, which faithfully represents the actual phenomena which are being computed. The propriety of assumptions, degrees of approximations, and use of one stability parameter to represent another in the T&S booklet were questioned, in the examination of this issue.

It would be most efficient if simply computed properties of the loading (deadweight, and longitudinal and vertical moments of deadweight) were used to check that the various operating criteria were satisfied. The naval architect already provides the information needed for this approach:

a. the fixed characteristics of the "deadweight" envelope

   - geometry of the vessel underwater shape (expressed by hydrostatic properties)
   - compartmentation (tankage, hold capacities and centers)
   - above-water shape (clearances, lateral projected area)
   - strength in bending, shear, and torsion
   - lightship weight and center of gravity

and

b. the criteria of stability and strength, the requirements for freeboard, etc. (from various regulatory bodies).

This information can be integrated and translated into maximum allowable values of (i) the deadweight, (ii) the first moments of the deadweight about horizontal, transverse vertical, and longitudinal vertical reference planes, and (iii) the shear and bending moment distributions along the length of the vessel (for strength).

The following components, found in virtually all of the T&S booklets examined are developed from this information.

- table of vessel's principal characteristics
- instructions for use of major components of the booklet: calculation of stability by long and short forms, use of vessel capacity plan, etc.
- summary of vessel's hydrostatic properties for a range of drafts
- trim table or diagram
- table of gain in GM by ballasting
- table or graph of required GM
- tables of tank capacities and free surface corrections
- cargo space and capacity data
- details of lightship condition
- sample loading conditions*
- damage stability
- bending moment numeral and instructions
- calculation forms - long forms
- calculation forms - short forms
- summary of fixed ballast.

No indices are provided. Hence quick and effective use of

* MarAd requires nine sample loading conditions to be incorporated in the T&S booklet for subsidized vessels (See Design Letter No. 3): 0, 10, 50% cargo with 0, 10, 50% consumables. The minimum USCG required number of conditions (Enclosure (1) to NVIC 3-73, Appendix 1) is four - 100% cargo with 10 and 100% consumables, and ballast with 0 and 100% consumables. Owners required numerous additional cargo loadings.

a given T&S booklet requires awareness of the location of the desired data in the specific book. Lightship details might be in vessel characteristics in one booklet, but shown separately in another, for example. The most marked divergences are in the tables of vessel characteristics and the text on the use of the booklet. The latter is highly developed in some cases but cut down into mere table headings in others. The subject treatment and format of many booklets appears to reflect the availability of loading manuals, operating handbooks, and other competing sources of stability guidance.

4.1 DISCUSSION AND EVALUATION OF COMPONENTS OF T&S BOOKLETS

The following discussion examines each section typically found in trim and stability books, using a cross-section of material taken directly from specific trim and stability books to illustrate wherever possible. The sections of the booklet are examined in the order in which they typically appear.

4.1.1 Principal Characteristics

This section gives a heterogenous selection of data, which are not always explicit, or consistent with the ship's plans and other tables in the booklet. LCGs, if given here, are referred to forward or after perpendiculars, less commonly to amidships. This section appears to serve as an aid to preparing the ship's paperwork rather than as an operational tool.

Useful 'principal characteristics' include name, builder, date and yard number of building, definition of lightship, class and registry, and principal dimensions. Sources of the booklet data should be briefly given.

Dimensions on the general arrangement and capacity plans should correspond with those given in this section. A reduced-detail version of the general arrangement plan should follow this section. Height above keel of highest fixed structure, and extreme dimensions, should be included to facilitate planning of port arrivals and departures.

4.1.2 Instructions

There is a relatively standard text describing the use of the booklet, particularly the two long forms for calculating GM. These instructions make reference to the successive tables and summary sheets used to perform the actual calculations, but no references to the worked examples are inserted in the text. Numbered paragraph format is standard. The instructions for calculation of stability and trim are often followed by instructions for determining the bending moment and shear force stresses, and remarks on "Routine Operating Instructions and Restrictions". *Some* of these instructions are superfluous, e.g. to press up ballast tanks. The implied aspersion on mariners' commonsense and professionalism could be dispensed with. A rationale for operating restrictions is seldom provided, and their operational implications/alternatives are not described. An explanation of restrictions and apparent anomalies, which could be read initially and later referred to when necessary, would be in line with the teaching function of the T&S booklet.

The comprehensibility of the instructions is poor, because of their unnecessary syntactical and structural complexity. A typical example follows. Note the excessive length of the lines, the unbroken paragraph

a given T&S booklet requires awareness of the location of the desired data in the specific book. Lightship details might be in vessel characteristics in one booklet, but shown separately in another, for example. The most marked divergences are in the tables of vessel characteristics and the text on the use of the booklet. The latter is highly developed in some cases but cut down into mere table headings in others. The subject treatment and format of many booklets appears to reflect the availability of loading manuals, operating handbooks, and other competing sources of stability guidance.

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OPERATING INSTRUCTIONS

THESE INSTRUCTIONS HAVE BEEN PREPARED AS AN AID TO OPERATING PERSONNEL IN CONNECTION WITH THE USE OF THIS TRIM AND STABILITY BOOKLET.

1. The Trim and Stability Booklet Provides:-

(a)	Page 1	Title or Cover Page
(b)	Page 2	Operating Instructions
(c)	Page 3	Table of Principal Characteristics
(d)	Page 4	Trim Table
(e)	Page 5	Hydrostatic Properties of Ship
(f)	Page 6	Summary of Capacities, Their Centers and Free Surface Effects.
(g)	Page 7 & 8	Graphs Showing The Lost In "GM" Due To Flooding.
(h)	Page 9	A Graph Of Cross Curves Of Stability.
(i)	Page 10	A Table Showing Draft Marks Location.
(j)	Page 11	A Blank Sheet To Write For Vehicle Data.
(k)	Page 12	A Blank Sheet For Determining The "GM" And Trim Of Vessel.
(l)	Page 13 To 24	Work Sheets Completed At Different Conditions Of Loading.

2. PROCEDURES:-

(a) In calculating the vessels' trim and stability by the direct method for any condition of loading, the detail weights in each category such as Cargo, Crew and Stores, Fresh Water, Fuel Oil, Ballast, etc., are entered in the Loading Table, Page 12, together with the vertical and longitudinal centers for each item, likewise, appropriate free surface correction for each tank containing liquids which is not pressed up, shall be entered. The Table, Page 6, gives data for the tank capacities, centers and free surface corrections, for tanks not pressed up. In the separate detail Loading Tables, Pages 13 to 24 are work sheets, showing use of Loading Table, Page 12. The summary of each column for weights, vertical moment, longitudinal moment (moment is the product of weight by center of gravity distance for each item) and free surface effect (i/δ) are taken.

(b) The Stability Condition Sheet or Loading Table, Page 12, finally sums the tonnage (weight), vertical moment, longitudinal moment and free surface results obtained above and includes lightship values. The total tonnage (weight) obtained is the vessels' loaded displacement. The loaded vessels' KG and LCG are determined by dividing the total vertical and longitudinal moment summations, respectively, by displacement. The Salt Water Mean Keel Draft corresponding to the total displacement is read from the Table of Hydrostatic Properties, Page 5, together with the transverse metacenter (KMt), Moment to Trim 1", LCF and LCB. These values are entered on the Stability Condition Sheet, Page 12. The KG (The VCG at total displacement) subtracted from KMt gives the GM of the vessel uncorrected for free surface. The free surface correction is obtained by dividing the total free surface (i/δ) by the total displacement and is subtracted from the uncorrected GM to arrive at the corrected available GM. ('δ' is the density in cubic feet per ton of the liquid in the respective tank)

(c) The distance between the vessels LCG and LCB is the trim lever. The product of displacement by trim lever is the moment causing the vessel to trim. When such moment is divided by "moment to trim one inch" (as found from the Curves of Form, Page 5) the vessels total trim in inches as measured on perpendiculars is determined. (When LCG is aft of LCB the vessel trims aft and vice versa.) The decimal of this total trim to be applied to the fwd. perpendicular is obtained by dividing the distance from the fore perpendicular to the LCF by the length between perpendiculars. The remainder of the total trim is applied to the aft. perpendicular Final Drafts on perpendiculars are found by applying these trim components to the mean keel draft corresponding to the displacement involved.

(d) All tons used in this booklet are long tons of 2240 pounds.

* Enter full free surface correction for the following service tanks; Fuel Oil contaminated Tanks and Settlers, Feed Water, Distilled Water, and Drinking Water Tanks. Not more than one pair of Tanks, except as mentioned shall be slack at any one time.

3. Routine Operating Instructions:-

(a) During the ballasting, a reduction in the vessels GM due to slack free surface will occur until the tank is pressed up. This temporary loss in GM (in feet) is equal to the Salt Water i/δ of the tank divided by the vessels displacement (in Long Tons) at the moment. (i/δ is the free surface effect as noted on Table, Page 6).

(b) Tanks required to be ballasted with Salt Water shall be immediately filled and carried pressed up at all times while such ballast is necessary. When not ballasted, such tanks shall be kept pumped to a minimum content at all times.

(c) Bilges shall be kept pumped to a minimum content at all times.

(d) This booklet contains calculations from Page 13 to 24, illustrating the use of Table, Page 12.

(e) The vessels operating GMs (corrected for free surface) shall at no time be less than those indicated on Pages 7 and 8.

format, and the arbitrary division into paragraphs of unequal importance. Each paragraph contains several instructions and the optimal sequence of calculation is left implicit. The "operating instructions" are - by format - placed on the same level of importance as the definition of a ton as 2240 lbs.

Instructions should be explicit and keyed to the range of stability aids aboard the vessel as well as to the booklet. Operational instructions should be demarcated from directions for calculating aspects of stability. The reading complexity of the instructions should be as low as consistent with the technical sophistication to be conveyed.

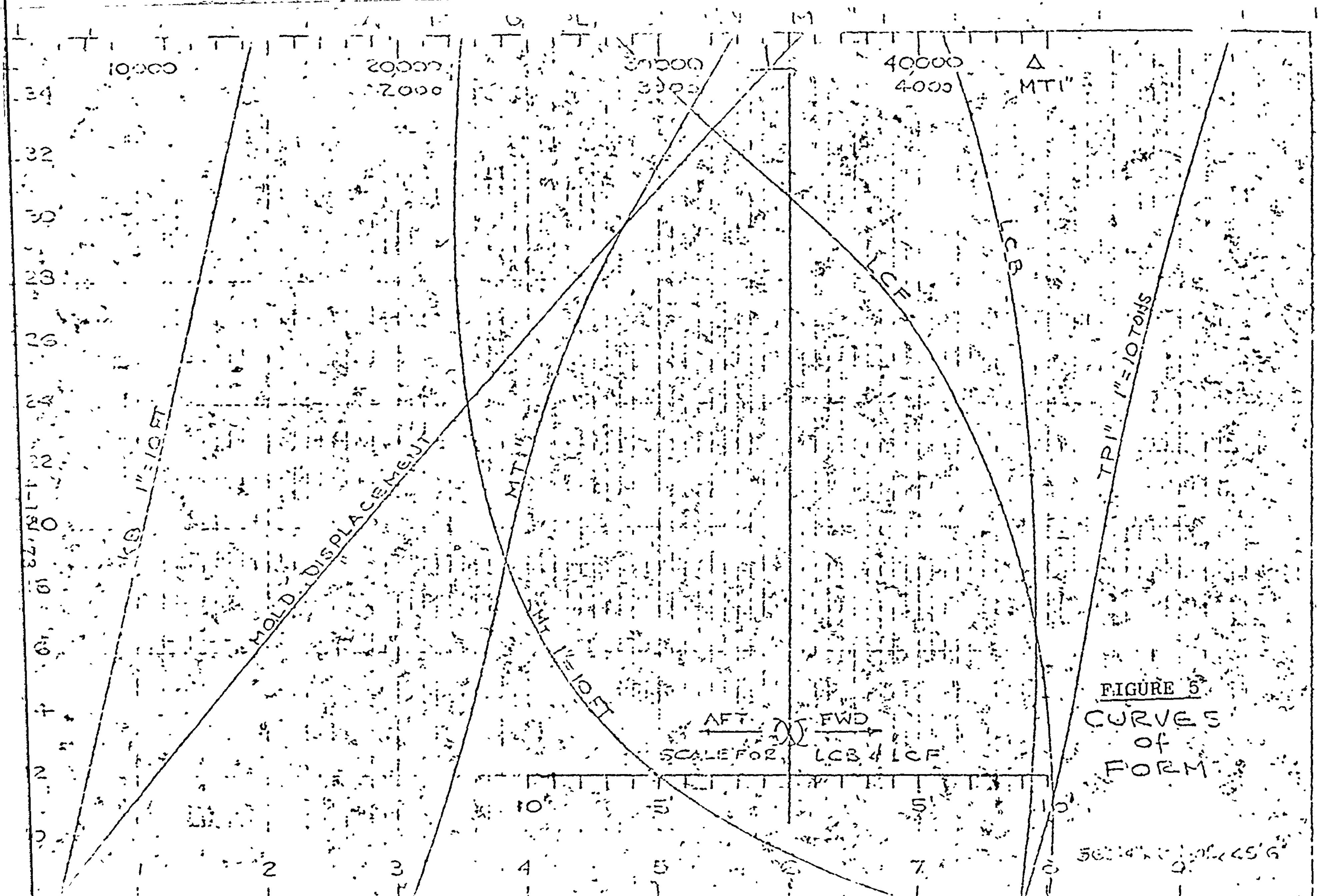
4.1.3 Summary of Vessel's Hydrostatic Properties

The hydrostatic particulars quantify the changes in properties of the underwater geometry of the vessel resulting from change of draft. The most important items are displacement, MTI, TPI, LCB, LCF, and KM. A dead-weight scale is sometimes included with the hydrostatic particulars. The values for these curves are calculated, tabulated, and plotted against values of the draft. Graphical formats are increasingly being supplemented or displaced by tabular formats suited for interpolation on the ubiquitous hand-held calculator.

Nine examples of hydrostatic formats are reproduced here. The quality of reproduction is equal or superior to the copy supplied for the contractor's use. The major formats and format/production problems are illustrated in these examples.

Figure 5 - Graphical Format

This format is uniquely suited to convey an appreciation of the change of trimming moment with



CURVES OF FORM

displacement for a vessel with appendages, but it asks the user to read, and keep distinct, *five* scales. The possibility of error is high, particularly since the labelling of the scales is poor, and would cause particular problems to a first-time user of a graphical format. The grid is badly obscured in the original and copy and makes an accurate reading difficult.

<u>Tables 15 and 16 - Tabular Formats</u>

Table 15 is not nearly as legible and accurate as it could be: there is no reason for hand-printing, which frequently copies worse than type. Table 16 shows the gain in legibility from better production. In both, intervals are suited for easy interpolation.

<u>Table 17 - Tabular Format</u>

This rather poor copy is the example of mixed systems of units. TPI and MTI are British, the others metric. Inconsistent units are a source of error, particularly where the vessel's trading pattern exposes her to mixed systems of quantifying cargo.

<u>Figures 6, 7, 8, 9, and 10 - Nomographical Formats</u>

These are included to illustrate the restrictive influences on format of 8x14 and 8x11 booklet size. In Figure 6, the length of the nomograph has been accommodated by a foldout which has become illegible with age. There is also a probability of loss or tears repaired with obscuring tapes. The scale interval of Figure 8, however, is legible and sufficient, whereas the

TABLE 15

HYDROSTATIC PROPERTIES

d (mean)	Δ (LT)	MT1" (ft-tons)	TPI (tons)	KM (ft)	LCB (+ aft)	LCF (+ aft)
24' 0"	28500	6030	139.8	62.95	27.75	49.00
3"	28900	6346	141.0	63.10	28.10	51.70
6"	29320	6490	142.2	63.15	28.50	53.7[illegible]
9"	[illegible]770	6600	143.2	63.15	28.75	54.70
25' 0"	30190	6685	144.2	63.10	29.15	55.65
3"	30600	6770	145.1	63.00	29.50	56.20
6"	31020	6845	145.9	62.85	29.80	5[illegible].60
9"	31460	6910	146.7	62.70	30.25	5[illegible].90
26' 0"	31900	6975	147.4	62.45	30.60	5[illegible].15
3"	32350	7040	148.0	62.25	30.95	5[illegible].35
6"	32800	7095	148.6	62.05	31.25	5[illegible].50
9"	33250	7155	149.2	61.80	31.65	5[illegible].65
27' 0"	33700	7210	149.7	61.60	32.00	5[illegible].75
3"	34150	7265	150.2	61.35	32.35	5[illegible].85
6"	34650	7316	150.7	61.15	32.70	57.95
9"	35100	7365	151.2	60.90	33.00	58.00
28' 0"	35550	7415	151.7	60.70	33.30	58.00
3"	36000	7466	152.2	60.50	33.65	58.05
6"	36490	7515	152.6	60.30	34.00	58.10
9"	36950	7565	153.1	60.05	34.35	58.10
29' 0"	37430	7610	153.5	59.85	34.60	58.15
3"	37900	7660	154.0	59.65	34.95	58.15
6"	38380	7710	154.4	59.45	35.25	58.15
9"	38850	7760	154.8	59.25	35.50	58.20
30' 0"	39310	7810	155.2	59.10	35.80	58.20
3"	39790	7870	155.6	58.95	36.15	58.20
6"	40260	7930	156.1	58.80	36.50	58.50
9"	40760	8000	156.6	58.65	36.80	58.85
31' 0"	41230	8100	157.1	58.5[illegible]	37.05	5[illegible].80
3"	41720	8280	157.8	58.[illegible]	37.3[illegible]	6[illegible].10
6"	42200	8440	158.6	58.40	37.65	64.00
9"	42670	8560	160.0	58.35	37.95	64.90
32' 0"	43160	8645	162.0	58.35	38.20	65.30
3"	43620	8720	162.9	58.10	38.50	65.35
6"	44110	8765	163.3	57.90	38.75	65.30
9"	44600	8800	163.6	57.65	39.00	65.20
33' 0"	45090	8835	164.0	57.45	39.30	65.05
3"	45600	8866	164.3	57.25	39.65	64.85
6"	46060	8895	164.5	57.10	39.80	64.60
9"	46550	8926	164.8	56.90	40.05	64.3[illegible]
34' 0"	4[illegible]030	8950	165.1	56.75	40.30	63.[illegible]
3"	47510	8975	165.3	56.60	40.55	63.60
6"	48000	9000	165.5	56.45	40.80	63.30
9"	48500	9025	165.8	56.30	41.05	62.95
35' 0"	49000	9050	166.0	56.15	41.30	62.60
3"	49500	9075	166.2	56.00	41.50	62.25
6"	50000	9100	166.4	55.90	41.75	61.90
9"	50500	9125	166.7	55.75	41.95	61.55
36' 0"	51000	9150	166.9	55.65	42.15	61.20
3"	51500	9170	167.0	55.50	42.30	60.90
6"	52000	9195	167.2	55.40	42.50	60.55
9"	52500	9220	167.4	55.25	42.65	60.25
37' 0"	53010	9240	167.6	55.15	42.80	59.90
3"	53510	9265	167.8	55.05	42.95	59.60
6"	54010	9290	168.0	54.[illegible]	43.10	59.25
9"	54510	9315	168.1	54.85	43.25	58.95
3[illegible]' 0"	55020	9335	168.2	54.75	43.40	58.65
3"	55520	9360	168.4	54.65	43.50	58.35
6"	56030	9385	168.6	54.55	43.60	58.00
9"	56560	9405	168.8	54.45	43.75	57.70
3[illegible]' 0"	57090	9430	169.0	54.35	43.85	57.40
3"	57600	9450	169.1	54.30	44.00	57.[illegible]
6"	58100	9470	169.2	54.20	44.10	56.75
9"	58610	9495	169.4	54.10	44.20	56.45

TABLE 16

HYDROSTATIC PROPERTIES

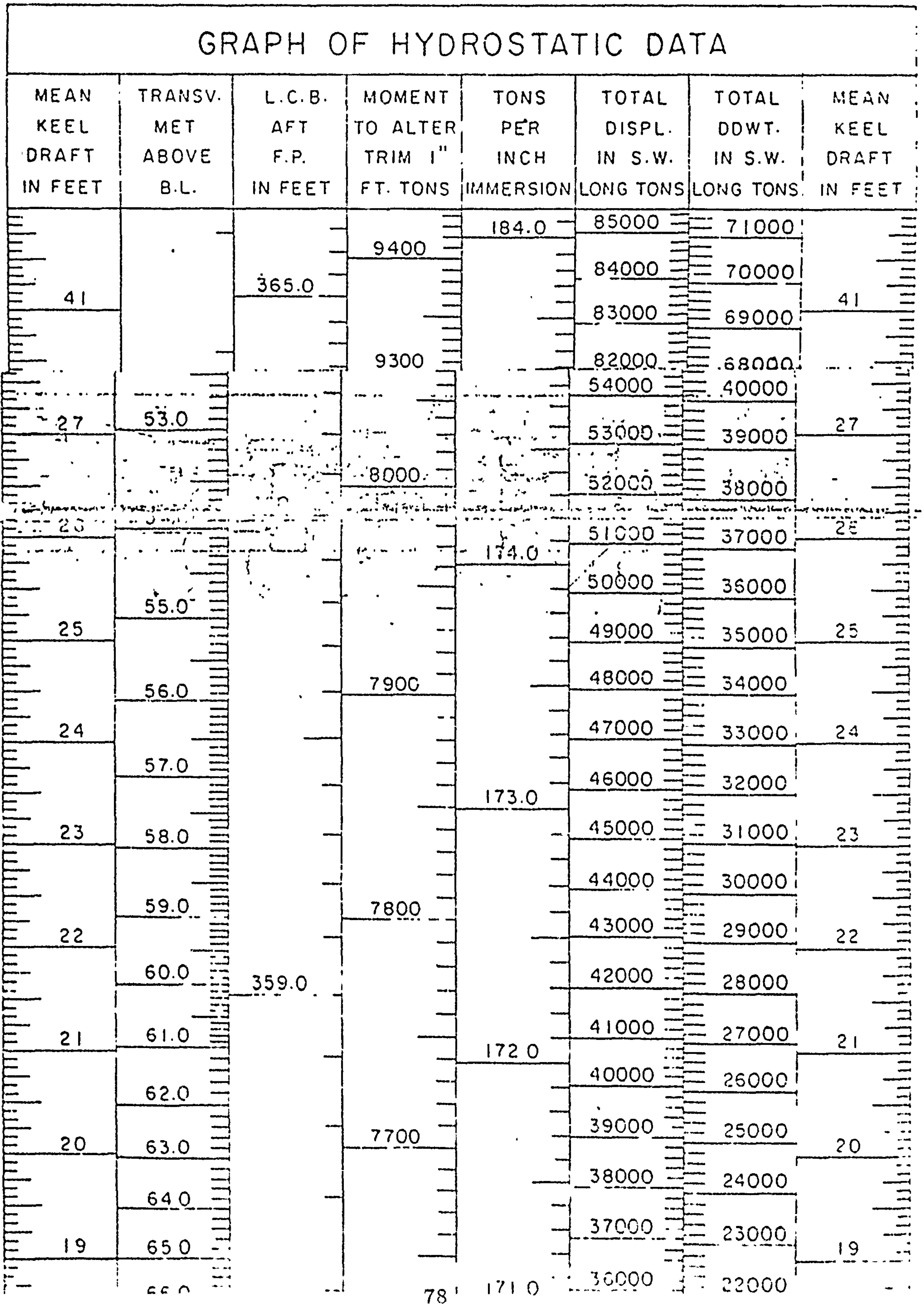
DRAFT (BOTT.OF KEEL)	DISPLACEMENT LONG TONS	MT1" FT-TONS	TPI L.T.	KM FT	LCB(FT) + ⊗ = FWD	LCF(FT) + ℄ = FWD
28'-0"	72650	11250	235	71.7	+0.52	-1.2
3"	73360	11270	235	71.4	+0.50	-1.12
6"	74075	11300	236	71.15	+0.50	-1.10
9"	74790	11320	236	70.85	+0.50	-1.05
29'-0"	75500	11350	236	70.50	+0.48	-1.02
3"	76200	11380	236	70.20	+0.47	-1.00
6"	76900	11440	237	69.90	+0.46	-0.70
9"	77650	11520	237	69.75	+0.46	-0.40
30'-0"	78360	11570	238	69.40	+0.45	0.00
3"	79200	11660	238	69.15	+0.46	+0.46
6"	79800	11730	239	68.87	+0.47	+0.90
9"	80500	11810	240	68.60	+0.46	+1.36
31'-0"	81200	11900	240	68.40	+0.46	+1.90
3"	81925	12010	241	68.10	+0.50	+2.70
6"	82650	12125	241	67.90	+0.52	+3.28
9"	83375	12140	241	67.60	+0.55	+3.17
32'-0"	84100	12160	242	67.40	+0.57	+3.07
3"	84825	12180	242	67.15	+0.60	+2.95
6"	85550	12200	242	66.92	+0.62	+2.85
9"	86275	12220	242	66.72	+0.65	+2.75
33'-0"	87000	12240	242	66.52	+0.67	+2.65
3"	87750	12260	242	66.30	+0.68	+2.55
6"	88500	12280	242	66.10	+0.70	+2.45
9"	89250	12300	243	65.85	+0.71	+2.36
34'-0"	90000	12330	243	65.70	+0.72	+2.28
3"	90800	12350	243	65.45	+0.75	+2.20
6"	91500	12370	243	65.30	+0.76	+2.10
9"	92200	12390	244	65.10	+0.78	+2.10
35'-0"	92980	12420	244	64.90	+0.79	+2.06
3"	93700	12450	245	64.79	+0.80	+2.05
6"	94400	12480	245	64.65	+0.80	+2.05
9"	95100	12520	245	64.45	+0.82	+2.07
36'-0"	95800	12550	245	64.30	+0.83	+2.12
3"	96500	12600	245	64.10	+0.85	+2.20
6"	97250	12640	245	63.10	+0.85	+2.26
9"	98000	12680	246	63.85	+0.85	+2.40
37'-0"	98725	12740	246	63.75	+0.87	+2.53
3"	99500	12810	247	63.60	+0.88	+2.80
6"	100250	12885	247	63.50	+0.90	+3.10
9"	101025	12970	248	63.30	+0.91	+3.35
37'-10"	101200	13010	248	63.25	+0.92	+3.50

TABLE 17

HYDROSTATIC PARTICULARS (in Salt Water S.G. 1.025)

Displacement (Tonnes [illegible])	T.P.I. (Tonnes per Inch Immersion)	M.C.T.I. (Mom. to Change Trim 1 Inch)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] (metres)
[illegible]7,185	184.7	2274.6	120.148	119.890	3.659	20.789	455.185
[illegible]8,[illegible]3	185.1	2278.9	120.139	119.794	3.763	20.453	442.550
[illegible]0,103	185,5	2238.5	120.128	119.750	3.866	20.141	432.[illegible]33
[illegible]1,5[illegible]8	185 9	2293.7	120.117	119.706	3.970	19.851	421.399
[illegible]3,035	18[illegible].3	2303.3	120.105	119.[illegible]7	4.073	19.531	411.[illegible]22
[illegible]4,506	186.6	2319.0	120.092	119.616	4.177	19.329	402.546
[illegible]5,930	187.2	2331.8	120.079	119.581	4.280	19.095	394.275
[illegible]7,[illegible]58	187.7	2345.8	120.066	119.552	4.384	18.877	33[illegible].621
[illegible]8,939	188.2	2360.3	120.053	119.516	4.487	18.674	379.386
[illegible]0,425	188.7	2375.1	120.039	119.476	4.591	18.484	372.558
[illegible]1,914	189.2	2392.9	120.025	119.456	4.695	18.308	366.468
[illegible]3,408	189.7	2411.0	120.011	119.430	4.799	18.143	360.720
[illegible],906	190.3	2429.8	119.998	119.399	4.903	17.990	355.290
[illegible],408	190.9	2448.9	119.934	119.[illegible]62	5.007	17.848	350.164
[illegible],915	191.5	2468.8	119.969	119.317	5.112	17.717	345.328
[illegible],427	192.0	2489.2	[illegible].954	119.266	5.216	[illegible]	340.770
[illegible],943	192.6	2507.6	[illegible].939	119.235	5.321	17.432	33[illegible].071
[illegible],463	193.2	2530.3	[illegible].924	119.158	5.425	17.378	332.[illegible]
[illegible]	193.[illegible]	25[illegible]4.7	[illegible].909	119.0[illegible]3	5.530	17.283	328.[illegible]5
[illegible]	194.6	25[illegible].4	[illegible]	1[illegible]8.9[illegible]	5.[illegible]35	17.[illegible]	325.[illegible]10
[illegible]	195.4	2[illegible]12.6	[illegible]	[illegible]18.[illegible]	5.[illegible]40	17.117	323.01[illegible]
[illegible]	[illegible].2	2[illegible]5.2	[illegible].8[illegible]5	118.59[illegible]	5.9[illegible]	17.015	320.747
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

FIGURE 6


GRAPH OF HYDROSTATIC DATA
MEAN KEEL DRAFT IN FEET
TRANSV. MET ABOVE B.L.
L.C.B. AFT F.P. IN FEET
MOMENT TO ALTER TRIM 1" FT. TONS
TONS PER INCH IMMERSION
TOTAL DISPL. IN S.W. LONG TONS
TOTAL DDWT. IN S.W. LONG TONS
MEAN KEEL DRAFT IN FEET
41
27
25
24
23
22
21
20
19
53.0
55.0
56.0
57.0
58.0
59.0
60.0
61.0
62.0
63.0
64.0
65.0
365.0
359.0
9400
9300
8000
7900
7800
7700
184.0
174.0
173.0
172.0
171.0
85000
84000
83000
82000
54000
53000
52000
51000
50000
49000
48000
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40000
39000
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71000
70000
69000
68000
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38000
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36000
35000
34000
33000
32000
31000
30000
29000
28000
27000
26000
25000
24000
23000
22000

FIGURE 7

HYDROSTATIC PROPERTIES

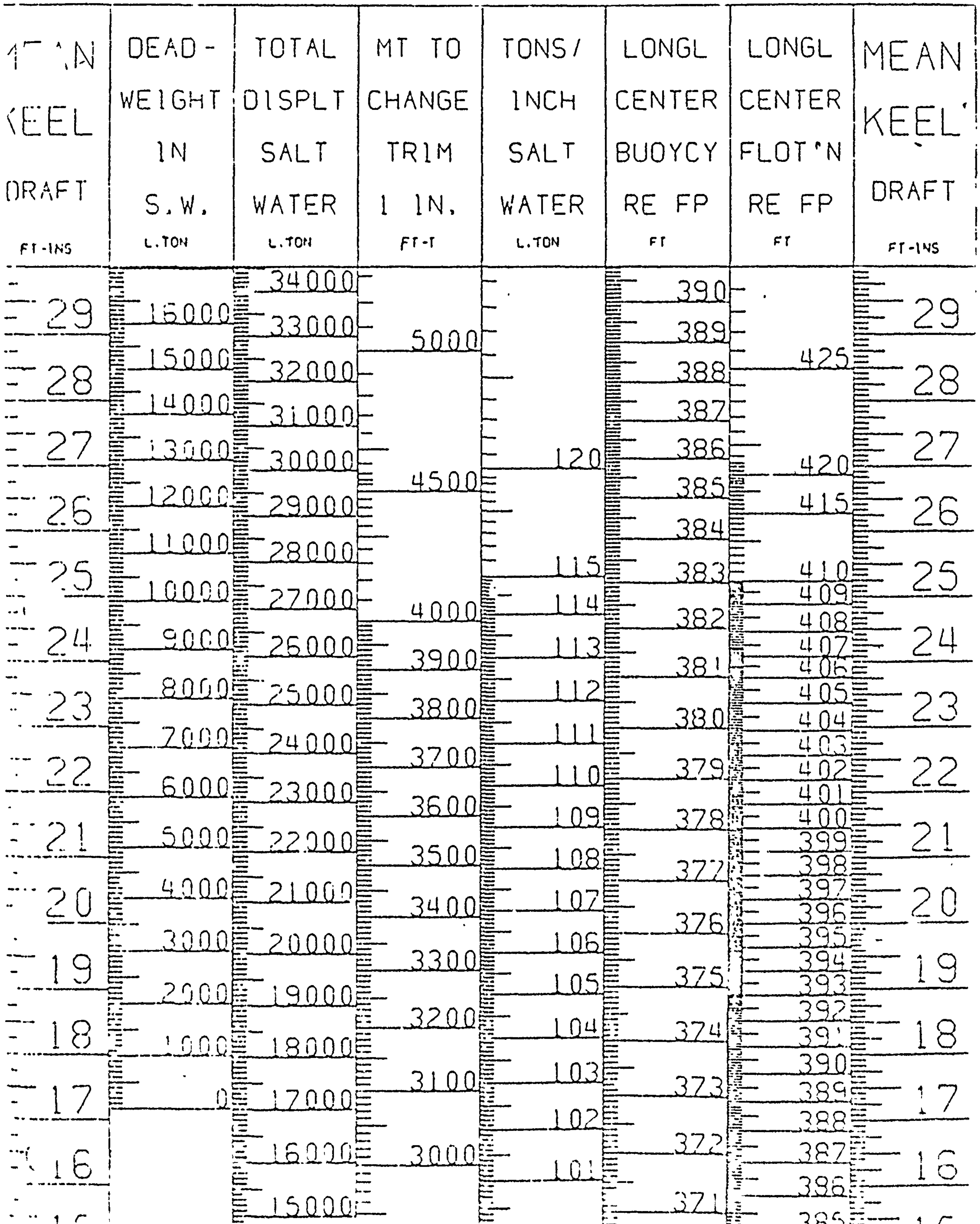


FIGURE 8

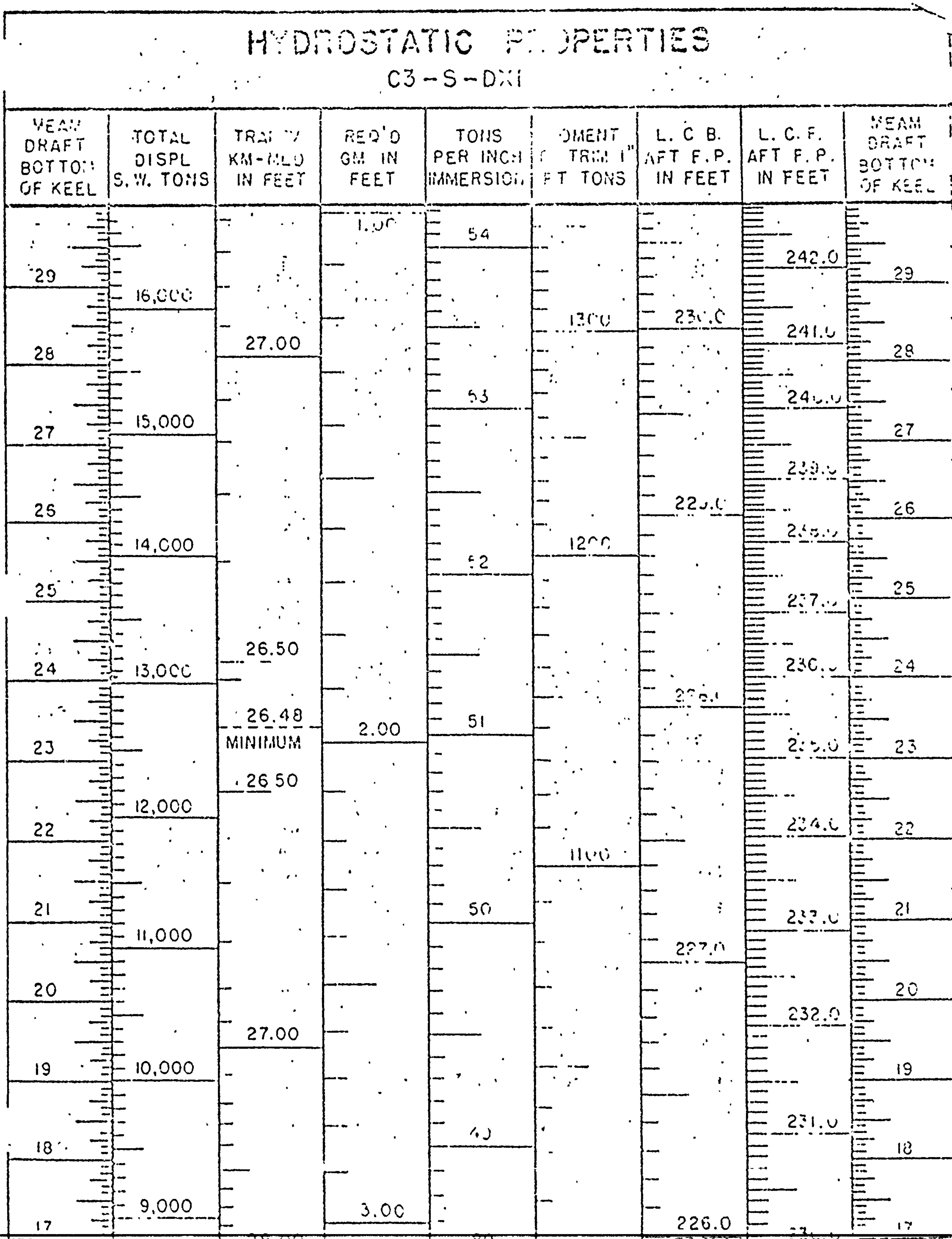

HYDROSTATIC PROPERTIES
C3-S-DXI
MEAN DRAFT BOTTOM OF KEEL
TOTAL DISPL S.W. TONS
TRANS KM-MLD IN FEET
REQ'D GM IN FEET
TONS PER INCH IMMERSION
MOMENT TO TRIM 1" FT TONS
L. C. B. AFT F.P. IN FEET
L. C. F. AFT F.P. IN FEET
MEAN DRAFT BOTTOM OF KEEL
29
28
27
26
25
24
23
22
21
20
19
18
17
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
27.00
26.50
26.48
MINIMUM
26.50
27.00
2.00
3.00
54
53
52
51
50
1300
1200
1100
226.0
242.0
241.0
232.0

FIGURE 9

HYDROSTATICS NOMOGRAPH

INSTRUCTIONS THE CENTER OF FLOTATION IS APPROXIMATELY AT ⊠ FOR THE DRAFT RANGE SHOWN. THEREFORE THE DRAFT AT THE LONGL CENTER OF FLOTATION IS READ DIRECTLY WHERE A STRAIGHT LINE CONNECTING THE DRAFTS AT THE FWD AND AFT MARKS CROSSES THE DRAFT ⊠ SCALE. ALL OTHER SCALES ARE READ BY PASSING A HORIZONTAL LINE THROUGH THE DRAFT AT ⊠.

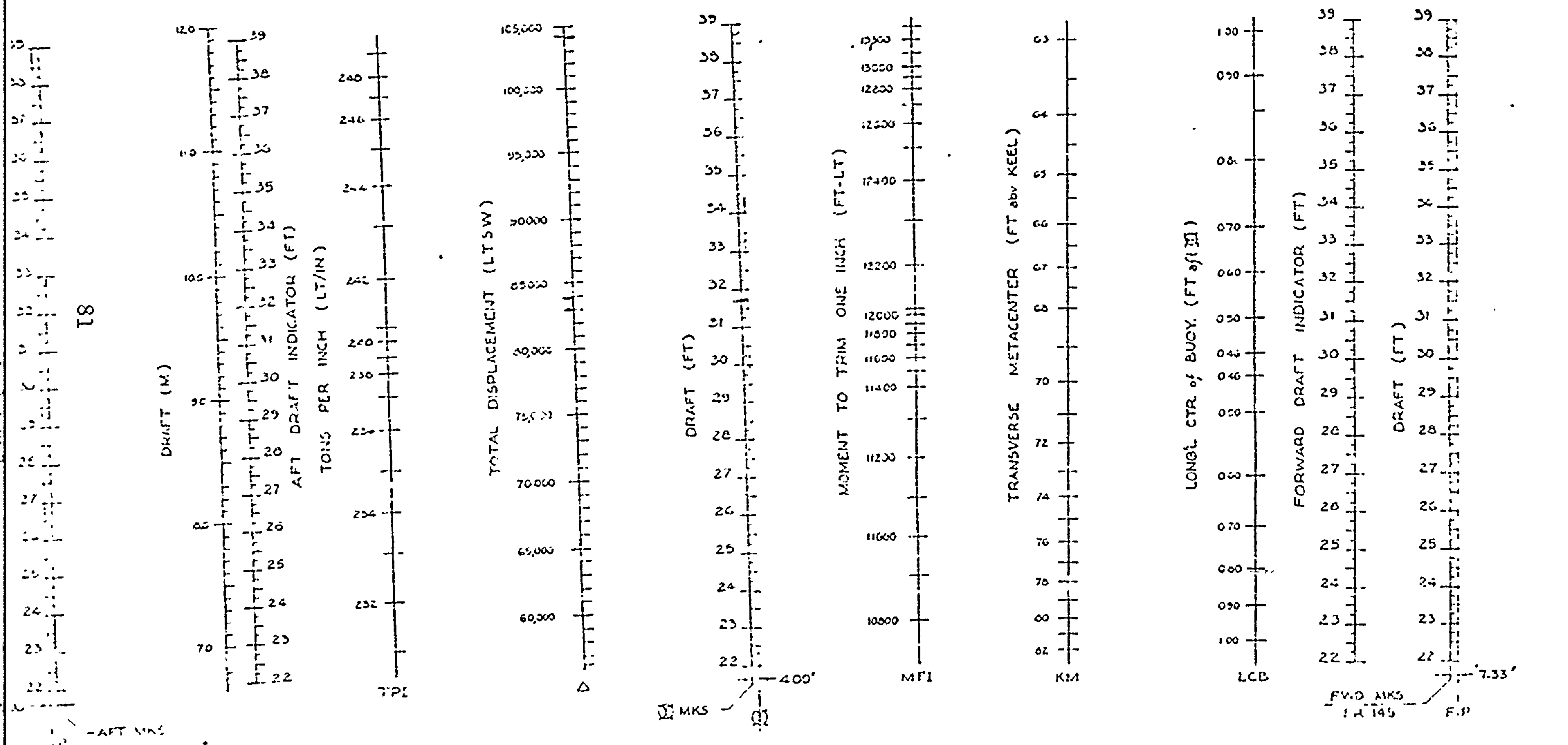
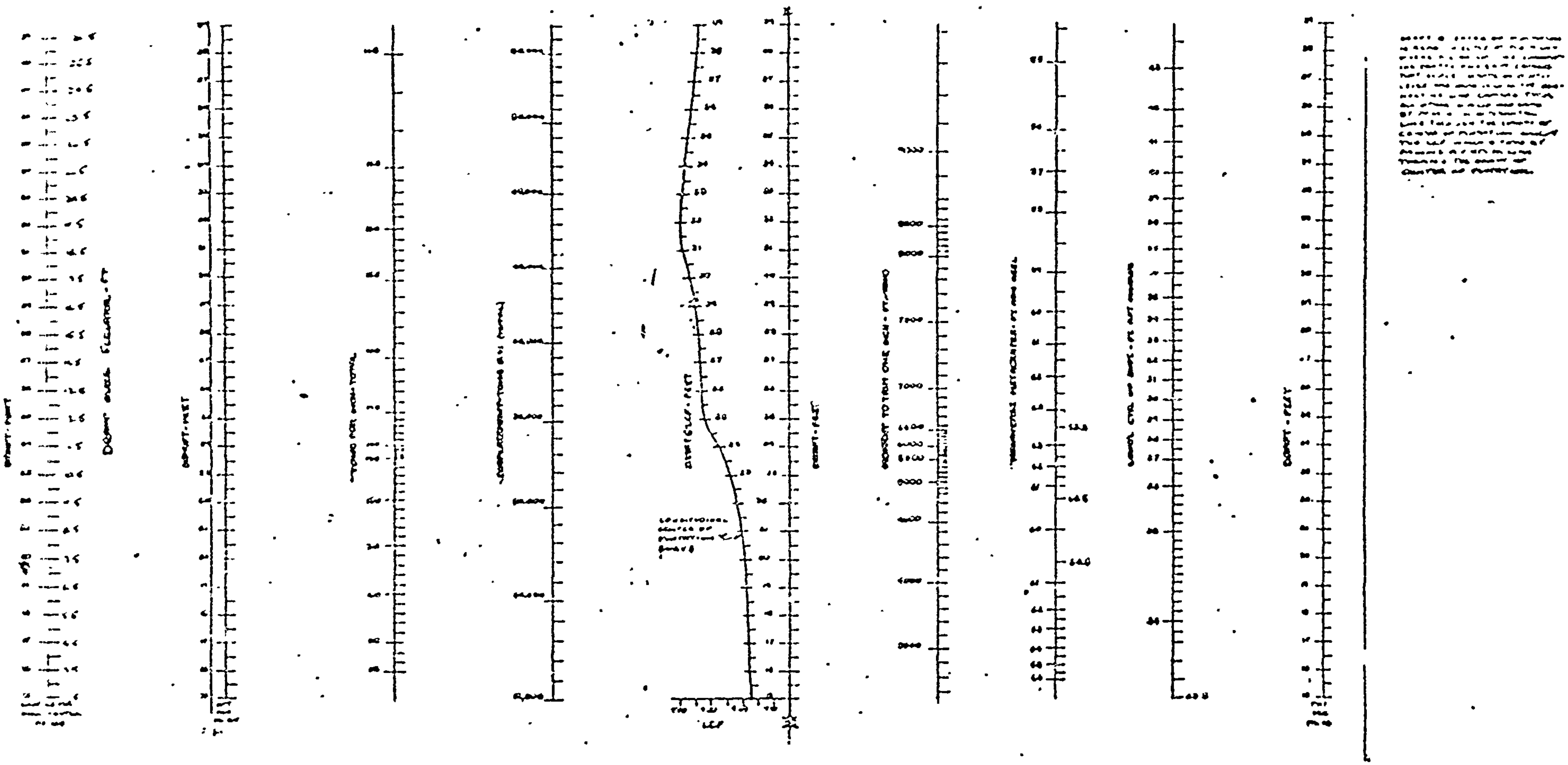


FIGURE 10 - HYDROSTATICS NOMOGRAPH



scale of Figure 7 is irreproducible. Figure 7 was included in its T&S booklet on two sheets, for convenience, and on neither are all the scales legible. The space devoted to large headings would have been better used to expand the scale size. Figure 10 is equally illegible despite a different presentation. Figure 9, clearly labelled, with legible scales, is one of the better examples of nomographic format.

Graphical and tabular presentations have their respective advantages, and including both may be appropriate. The graph vividly illustrates the results of the unfamiliar geometry of new types of vessels. The tabular presentation is easier and faster to use, particularly since interpolation is normally done on a hand-held calculator. Preference should be given to computer-generated tables with 3" draft intervals made up for a set of selected trim values. Both presentations should cover the range of mean drafts from lightship to maximum displacement. An extension table covering extreme drafts, e.g. for drydocking or overloaded conditions, may be supplied but is better kept separated from the ordinary range of information. Hydrostatic data applicable to damaged conditions, in whatever form is selected, should be included in the damaged stability material, if it is intended to supply this. The trim and other assumptions of such data need to be made explicit.

Even-keel properties of the shipform underlie all these existing nomographic, tabular, and curves-of-form presentations of hydrostatic information. For most cases, where the trim is less than L/150, and where the waterplane does not significantly change in shape with trim, use of such presentations is satisfactorily accurate.

Significant errors can result when the hydrostatic properties change rapidly with mean draft and the longitudinal center of flotation is not near amidships, which occurs with barge carriers and gas carriers. An amidships draft is used initially to enter the hydrostatics table or graph of these vessel types to obtain an LCF draft. The properties LCB, MTI, TPI, and KM are then read at the LCF draft. See Figures 9 and 10.

When operational trims are such as to invalidate the use of an 'even-keel' presentation of hydrostatic information, a Van Der Ham diagram should be used. See p 90.)

Tabular deadweight and displacement scales and a tabulation of required GM* should be located adjacent to the hydrostatic properties, together with a diagram showing the load line assigned and the corresponding freeboard. One such presentation is shown in Section 6.3, p 195. Where there is no unique value of required GM for each displacement, the separate graph *may be more suitable*. The graph allows better linking of the instructions for choosing and using a curve of GM to the curve itself, and displays any peculiarities of the GM requirement.

4.1.4 Trim Table or Diagram

Trimming tables are derived directly from the hydrostatics information. Their value lies in their ease of understanding, quickness of calculation, and value in working "backwards" from actual and desired trim and draft, to amount and location of cargo addition/removal/transfer. This table incorporates

* Alternatively, stability requirements may be expressed in graphs of maximum allowable VCG. The graph of maximum VCG gives an equivalent result. The VCG method obviates looking up the KM value and subtracting KG to get GM.

information on tank centers and the hydrostatics and is usually given for more than one draft level. It suffers from the same inaccuracy inherent in the hydrostatics tables when considering trimmed conditions as well as assumed and actual mean draft.

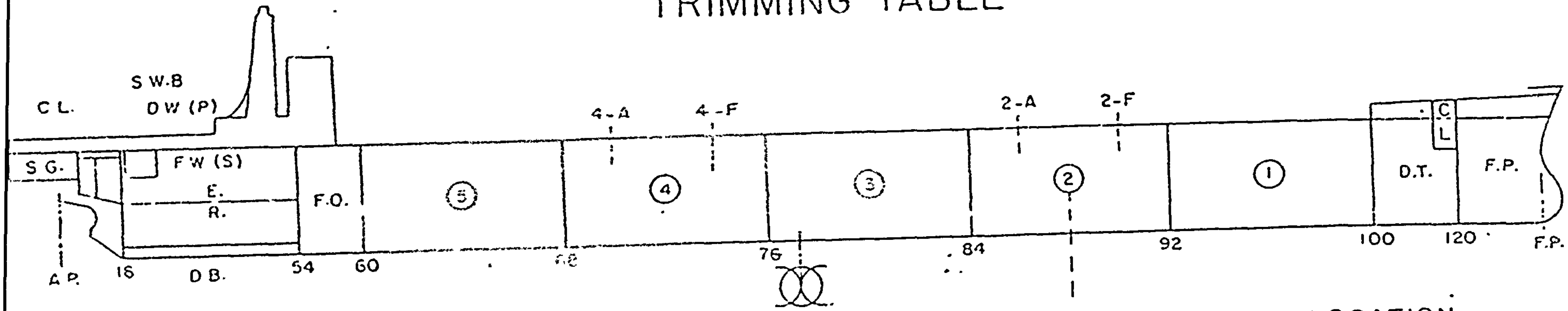
There are two major types of trim tables/ diagrams. The conventional trimming table - generally derided as inaccurate because LCF and MTI change with trim - allows the effect of incremental loads/discharges to be estimated. The Van Der Ham diagram indicates forward and aft drafts for values of displacement and longitudinal moment of weight. This format is more accurate because it takes into account changes in hydrostatic properties with change in trim. It is more flexible in planning trim and uses the moments principle underlying other cargo calculations.

As presently set out, the conventional trim table does not present difficulties in comprehension, so much as difficulties in accuracy and ease of use. The size of the figures is usually far too small. Figures and headings are frequently oriented in conflicting ways. Though it is not done, the instruction should be placed at the head or top of the page, before the table it explains. Table 18 is the most legible example found of this type, yet the scale reads vertically, despite the horizontal set imposed by the horizontal instructions and ship profile data. Table 19 has the same orientation problem, but increases the overall difficulty in using the table by a) hand-lettering in a slant italic hand (very difficult to read, and obtrusively individualistic) and b) using small hand-printed numerals. Table 20 takes the hand print to its ultimate conclusion by adopting total illegibility.

The two trim diagrams, Figures 11 and 12, can both

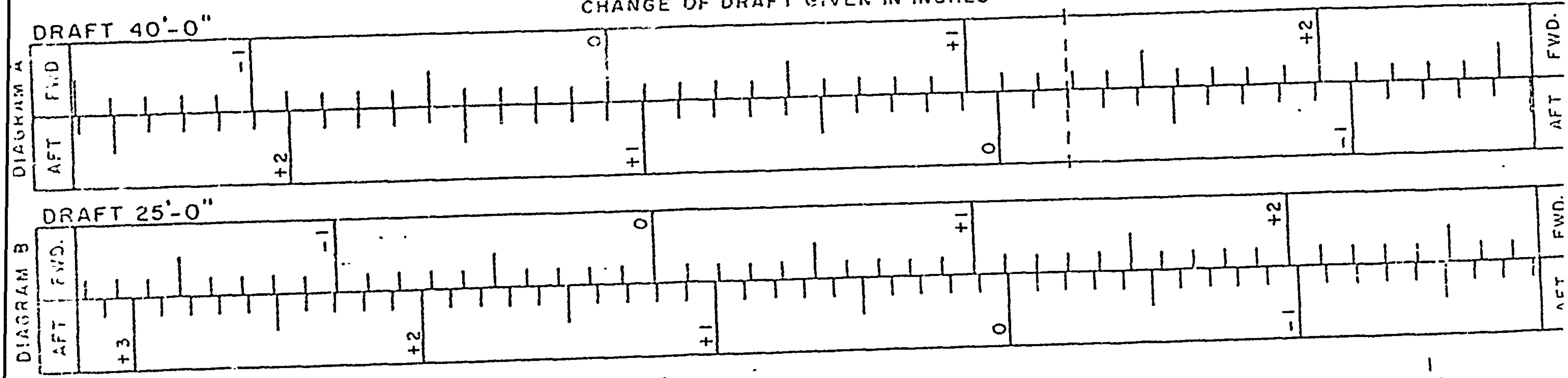
TABLE 18

TRIMMING TABLE



EFFECT ON DRAFTS FOR EACH 100 TONS LOADED AT ANY LONGITUDINAL LOCATION

CHANGE OF DRAFT GIVEN IN INCHES



EXAMPLE: FIND CHANGE IN DRAFT AFTER LOADING 500 TONS IN NO. 2 CTR. TANK

	FORWARD	AFT
ORIGINAL DRAFTS	39' 5/8"	40'-1"
CORRECTION - FROM TABLE MARKED 40'-0" DRAFT DIRECTLY BENEATH THE WEIGHT 5 X (1.28") =	+ 0'- 6 3/8"	5 X (-0.20") = - 0'-1"
NEW DRAFTS	40'-0"	40'-0"

NOTES: 1. THE CORRECTIONS WERE COMPUTED FOR THE TWO DRAFTS 15'-0" APART TO FACILITATE INTERPOLATION, BUT IN PRACTICE WILL BE SUFFICIENTLY ACCURATE TO REFER TO THE TABLE NEAREST THE SHIP'S DRAFT.

2. WHEN DISCHARGING, USE THE TABLE AS FOR LOADING AND CHANGE THE + AND - SIGNS.

TABLE 19

TRIM TABLE

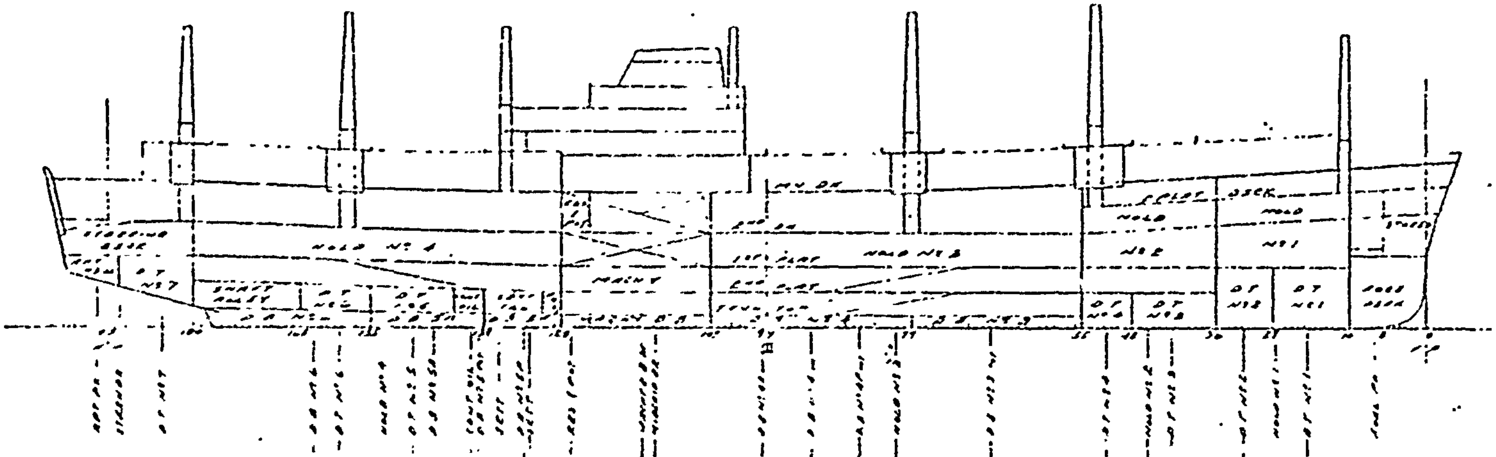


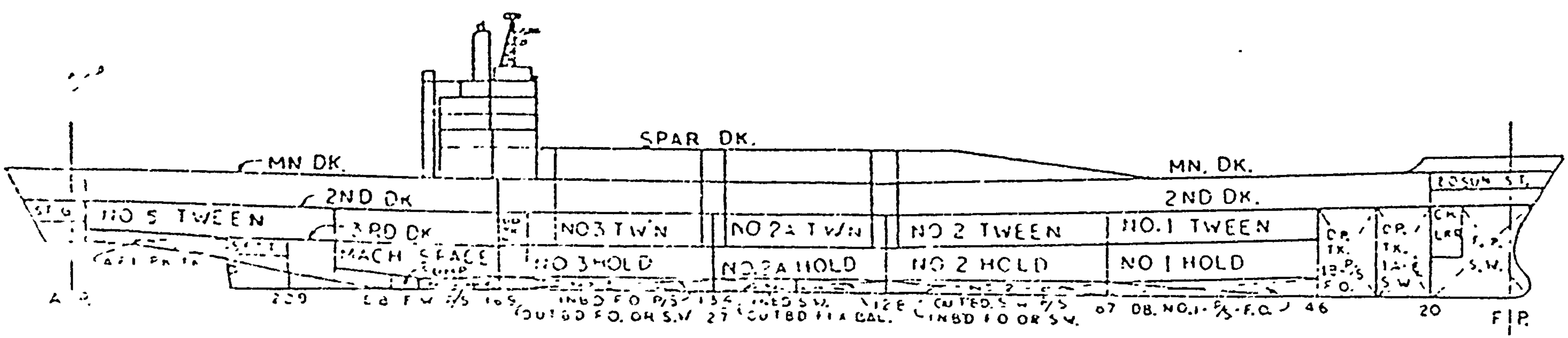
TABLE OF VARIATIONS (IN INCHES) OF FWD & AFT DRAFT FOR EACH 100 LT LOADED @ ANY LONG'L LOCATION.

INITIAL EVEN KEEL DRAFT		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
27'-0"	FWD	[illegible]	-4.5	-4.2	-3.9	-3.6	-3.2	-2.9	-2.5	-2.2	-1.8	-1.4	-1.1	-0.7	-0.4	0.0	+0.4	+0.7	+1.1	+1.4	+1.8	+2.2	+2.5	+2.9	+3.2	+3.6	+4.0	+4.3	+4.7	+5.0	+5.4	[illegible]	+6.1	+6.5	+6.8	+7.1	+7.5	+7.8	[illegible]	[illegible]	+8.6	[illegible]
27'-0"	AFT	+6.2	+6.0	+5.8	+5.5	+5.3	+5.0	+4.8	+4.5	+4.2	+4.0	+3.7	+3.4	+3.1	+2.8	+2.5	+2.3	+2.0	+1.7	+1.4	+1.2	+0.9	+0.6	+0.3	+0.1	-0.2	-0.5	-0.8	-1.1	[illegible]	[illegible]	-1.9	-2.2	-2.4	-2.7	-3.0	-3.2	-3.4	-3.7	[illegible]	-4.1	-4.3
22'-0"	FWD	-5.5	[illegible]	[illegible]	-4.5	-4.2	-3.8	[illegible]	-3.0	[illegible]	-2.2	-1.8	-1.4	[illegible]	[illegible]	-0.2	+0.2	+0.6	+1.0	+1.4	+1.8	+2.2	+2.6	+3.0	+3.4	+3.8	+4.2	+4.6	+5.0	+5.4	+5.8	+6.2	+6.6	+7.0	+7.4	+7.7	+8.1	+8.4	[illegible]	[illegible]	[illegible]	+9.7
22'-0"	AFT	+7.1	[illegible]	[illegible]	[illegible]	+6.1	[illegible]	+5.5	[illegible]	[illegible]	[illegible]	+4.2	+3.9	+3.5	+3.2	+2.9	+2.6	[illegible]	[illegible]	+1.6	[illegible]	+1.0	+0.7	+0.4	0.0	-0.3	-0.6	-0.9	-1.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-3.2	[illegible]	[illegible]	-4.0	[illegible]	[illegible]	[illegible]	-5.0
17'-0"	FWD	-6.7	-6.3	[illegible]	[illegible]	-5.2	-4.7	-4.3	[illegible]	[illegible]	[illegible]	-2.5	-2.0	-1.5	[illegible]	-0.6	-0.2	+0.3	+0.7	+1.2	+1.7	+2.1	+2.6	+3.0	+3.5	+3.9	+4.3	[illegible]	[illegible]	[illegible]	[illegible]	+6.7	+7.1	+7.6	[illegible]	+8.4	[illegible]	+9.2	[illegible]	[illegible]	[illegible]	+10.7
17'-0"	AFT	+8.7	+8.4	+8.1	[illegible]	+7.4	+7.1	[illegible]	+6.3	[illegible]	+5.5	+5.1	+4.7	+4.3	+3.9	+3.5	[illegible]	+2.8	+2.4	+2.0	+1.6	+1.2	+0.8	+0.4	0.0	-0.3	-0.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

EXAMPLE [illegible] FWD & AFT DRAFTS AFTER LOADING 200T IN D.T. NO. 7
ORIGINAL DRAFT FWD 22'-3" AFT 23'-0"
[illegible]
NEW DRAFT FWD [illegible] AFT [illegible]

NOTE: [illegible]

TABLE 20 TRIM TABLE



20'-0" DRAFT	350	300	250	200	150	100	50	℄	50	100	150	200	250	300	350
AFT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FWD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

27'-0" DRAFT	350	300	250	200	150	100	50	℄	50	100	150	200	250	300	350
AFT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FWD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NOTE:

The above Trim Table indicates draft corrections in inches at fwd and aft draft marks when a weight of 100 tons is loaded at a given distance from midship.

When discharging weights, use table as in loading with plus and minus signs reversed.

EXAMPLE:

Find new drafts after loading 100 tons in No. 1 hold (210'-0" fwd of amidship):

	Fwd		Aft
Initial Drafts	21'-4"		25'-8"
	+ 0'-4.31"		- 0'-1.67"
	21' 8-3/8"		25' 6-3/8"

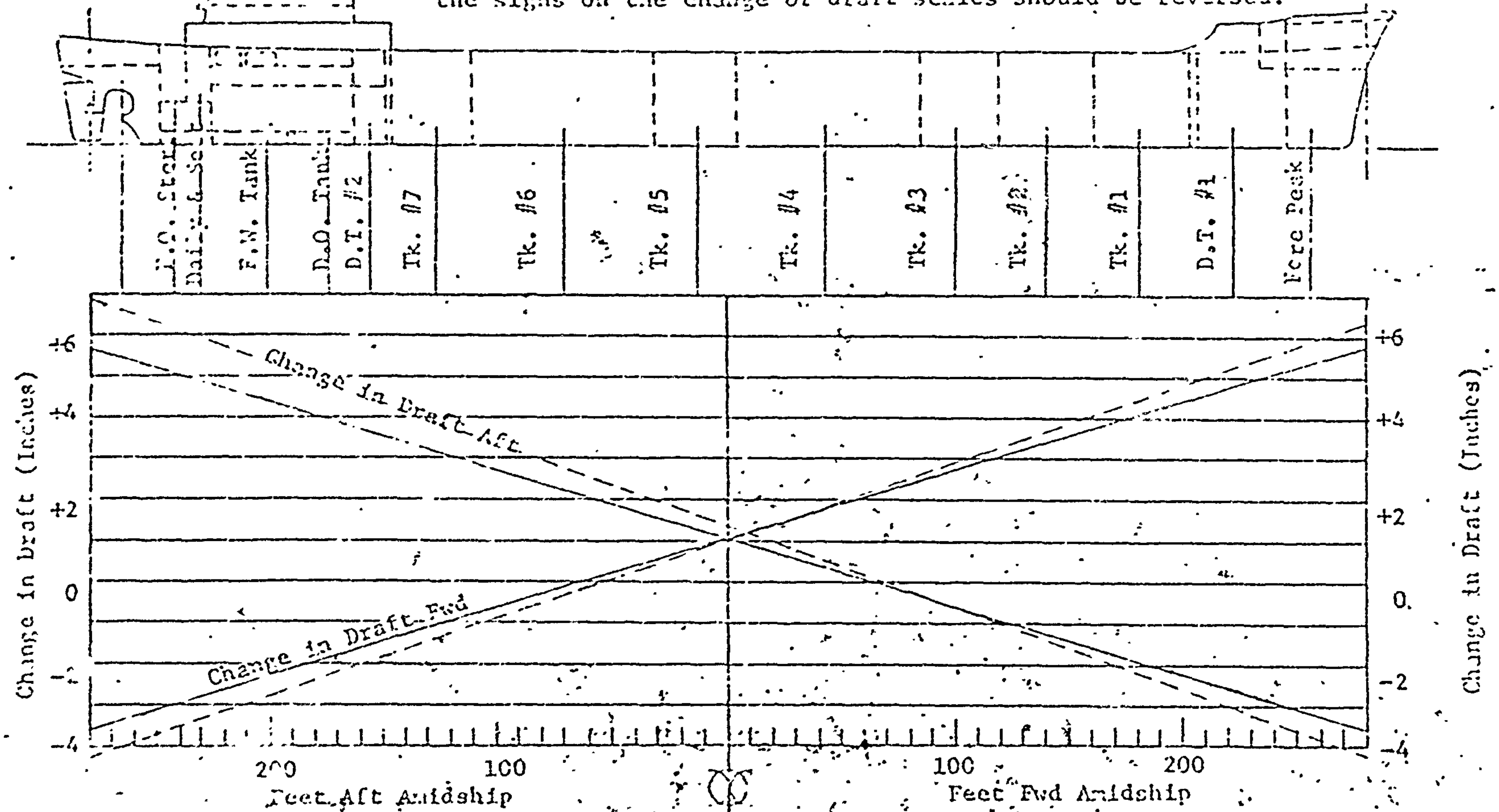
CORRECTION:
(Interpolated between tables for a mean draft of 23'-6")

New Drafts (To Nearest 1/8")

FIGURE 11

Trimming Diagram

The diagram illustrates the effect on the draft at the perpendiculars of adding 100 tons at any location in this ship. If weights are removed, the signs on the change of draft scales should be reversed.



Full Lines Indicate Properties of 32'-0" W.L.

Dashed Lines Indicate Properties of 24'-0" W.L.

Example: 150 Tons added in Tank No. 2 with Ship at 24'-0" Draft

Change in Draft Fwd = 1.5 x (+3.65) = 5.48"

Change in Draft Aft = 1.5 x (-1.40) = 2.10"

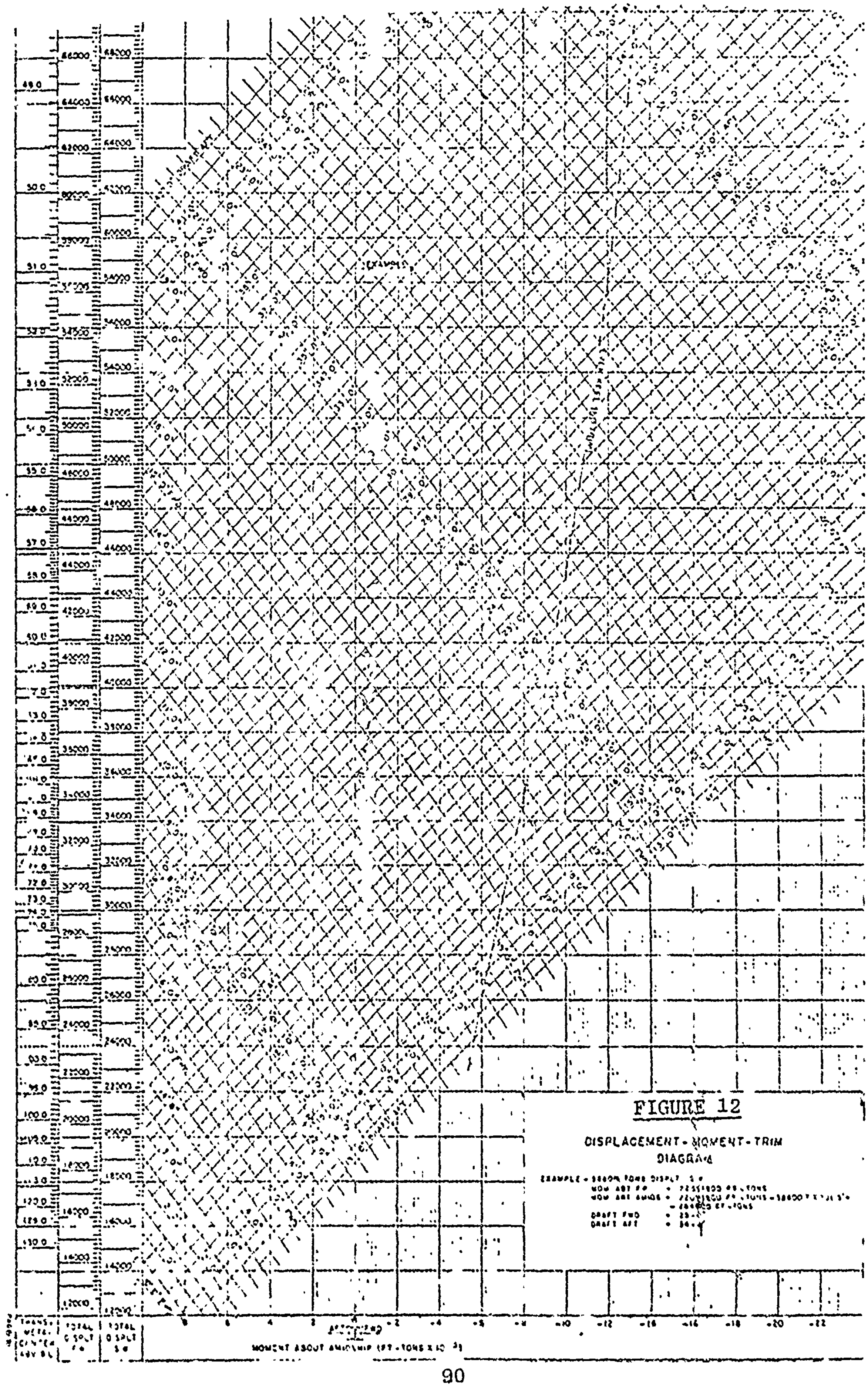


FIGURE 12

DISPLACEMENT-MOMENT-TRIM DIAGRAM

be read from one perspective. The relative visual clarity of Figure 11, which is a blueprint, is offset by its lesser accuracy - this is simply a graphical presentation of a two draft trimming table. The Van Der Ham diagram, Figure 12, is more difficult to read, without the use of color or a differentiated grid to help the diagram stand out against its field. Its potential usefulness is severely curtailed by legibility *in this instance.*

The Van Der Ham presentation of forward and aft drafts as a function of displacement and LCG (or their equivalents) is very accurate. Its construction requires careful design calculations (to incorporate appendage effects and accurately analyze vessel end geometry) which are readily performed using a computer. Since displacement and LCG uniquely determine the draft and trim of a given vessel, the accuracy of the Van Der Ham graph is solely dependent on the accuracy of the weight and moment calculations.

Means of determining the increase in draft, due to list, should be provided by tables relating angular heel read from inclinometer to draft increase. See p 209 Section 6.3.

4.1.5 Gain in GM Due to Ballasting

The table of increase in GM by ballasting is based on information from the tank capacities and centers table and the vessel hydrostatics. It assumes an initial vessel displacement. In some cases the table is presented for several displacement (draft) levels. Its primary advantage is the quickness it affords in analyzing small changes.

This table lists usual ballast tanks and their effect on GM at various drafts or displacement. Additional tanks - fresh water, sanitary, etc. - are not entered, and no attempt is made to consider the effects of the ballasting

choice on trim, list, or seakeeping properties* of the vessel. It cannot be said, therefore, that this table really meets the objective of enabling the user to weigh the "relative advantages of the ballast tankage available to him". Two typical presentations are Tables 21 and 22. The grid is seen to be helpful when the two are contrasted, even if allowance is made for the small number of tanks in Table 21.

Vessels with high ballast tanks - LNG tankers, barge carriers - employ tables of net effects on GM from ballasting or deballasting. This recognizes their capacity for increasing GM by removal of high weight as well as addition of low weight. However, in these tables, as in the older type, there is no attention to the additional effects of ballasting operations, and no systematic guidance to the user in optimizing the selection of tankage and sequence of filling/emptying.

Two such tables of net effects are Tables 23 and 24. The extremely clear layout of Table 23 unfortunately leads to a rather unwieldy section, whose dispersed layout prevents at-a-glance identification of likely combination of tanks. The physically crowded layout of Table 24 would be easier for a new user, particularly one unacquainted with the vessel type.

4.1.6 Table or Graph of Required GM

The values of required GM for most commercial vessels are developed from damage stability and weather criteria. Curves are plotted for the respective criteria, then superimposed, in effect, and a final composite curve

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* Rolling period, heading stability, seakindliness, etc.

TABLE 21

GAIN IN GM BALLASTING TANKS, FEET			
DISPLACEMENT LONG TONS	NO 4 AFT D.B. TANK	FORWARD D.TK. P & S	FORWARD PEAK TANK
	61.00	788.76	403.11
20,000	+0.07	+0.41	+0.27
18,000	+0.07	+0.50	+0.27
16,000	+0.07	+0.37	+0.20
14,000	+0.09	+0.33	+0.20
12,000	+0.09	+0.20	+0.13
10,000	+0.16	+0.03	+0.08

NOTE: 1. FOR DIFFERENT DISPLACEMENTS THAN SHOWN, INTERPOLATE BETWEEN VALUES GIVEN.
2. WHEN DEBALLASTING USE THE TABLE AS FOR BALLASTING AND CHANGE THE + AND − SIGNS

TABLE 22

TABLE OF GM GAIN VS. DISPLACEMENT FOR BALLAST TANKS

			(GM GAIN IN FT.) INITIAL DISPLACEMENT LONG TONS IN S.W.							
VCG	TANK	S.W. CAP'Y. 100% (L.T.)	18,000	20,000	22,000	24,000	26,000	28,000	30,000	32,000
22.5	Forepeak	429.4	.183	220	.247	.275	.260	.190	.209	.213
31.4	D.T. 1A	574.	-.031	.053	.127	.154	.157	.072	.107	.127
31.4	D.T. 18-PS	971.9	-.014	.094	.185	.246	.259	.134	.169	.202
4.0	D.B. 21-PS	820.8	1.367	1.154	1.140	1.106	1.055	.896	.874	.855
4.9	D.B. 20-PS	535.4	.725	.738	.743	.730	.631	.569	.563	.555
3.[illegible]	D.B. 2A1-PS	721.	1.042	1.020	1.012	.992	.931	.791	.777	.755
4.5	D.B. 30-PS	739.8	1.034	1.020	1.011	1.000	.938	.800	.783	.761
18.6	D.T. Aft PS	645.	.398	.472	.477	.511	.487	.379	.383	.395
28.4	Aft Peak ℄	835.9	.103	.200	.279	.316	.315	.207	.229	.250
31.6	Aft Peak PS	245.6	-.042	.043	.038	.068	.071	.034	.038	.053
14.5	SternTubeCompt.	202.1	.155	.216	.188	.207	.190	.155	.142	.151

NOTE: These values are computed from and intended primarily for conditions where calculated available GM approaches the limits defined by the Required GM Curve (page 15), and are <u>not</u> intended to preclude the remainder of the complete stability calculation. They are intended <u>only</u> for the convenience of the Master in ascertaining the relative advantages of the ballast tankage available to him.

TABLE 23

NET EFFECT ON KG BY BALLASTING TANKS (IN FEET)

SWB No. 1

LVL (FT)	DRAFT 30 FT	DRAFT 36 FT	Notes
12	-0.02	-0.02	
24	-0.07	-0.05	
36	-0.10	-0.07	
48	-0.08	-0.05	
62.29	+0.01	+0.04	
62.29	-0.44	-0.33	Pressed Up

SWB No. 2 P&S

LVL (FT)	DRAFT 30 FT	DRAFT 36 FT	Notes
2	-0.03	-0.02	
6.3	-0.25	-0.19	Innerbottom
10	-0.45	-0.36	
20	-0.83	-0.65	
30	-1.15	-0.91	
47.54	-1.[illegible]5	-1.14	
71.44	-1.50	-1.16	Slack or Pressed Up

Note: Table values for wing tanks are for <u>both</u> tanks filled to the level indicated.

TABLE 24

APPROXIMATE GAIN IN GM BY BALLASTING OR DEBALLASTING

GAIN IN GM BY BALLASTING (IN FEET)

S.W. BALLAST TANK, CAPACITY (IN LONG TONS)

MEAN DRAFT (FT.)	F.P. 3035	W.T.#1 P&S 9003	[illegible] P&S 2565	L.M.T.#2 P&S 7712	[illegible] P&S 2923	[illegible] P&S 7062	[illegible] P&S 1035	[illegible] P&S 2730	[illegible] P&S 2415	[illegible] P&S 7062	[illegible] P&S 2923	[illegible] P&S 6750	[illegible] P&S 5633	D.C. 902	AFT D.T. 4043	A.P. 2150	S.T.#1 4017	S.T.#2 2727
30	-0.7	-1.1	-2.1	0.1	-2.2	0.4	-0.8	0.1	-2.0	0.4	-2.2	0.3	-2.4	0.1	-1.2	-0.6	-2.2	-1.6
32	-0.3	[illegible]	-1.6	0.6	-1.7	0.9	[illegible]	[illegible]	-1.5	0.8	-1.7	0.7	-1.7	0.3	-0.4	-0.3	-1.0	-1.2
34	-0.2	-0.2	-1.3	0.7	-1.6	1.0	-0.5	0.4	-1.4	1.0	-1.6	0.3	-1.5	0.2	-0.4	-0.3	-1.5	-1.2
36	-0.3	-0.1	-1.4	0.3	-1.3	1.0	-0.6	0.4	-1.3	1.0	-1.5	0.9	-1.4	0.2	-0.4	-0.3	-1.5	-1.0
38	-0.2	0.1	-1.2	0.9	-1.2	1.2	-0.4	0.5	-1.1	1.2	-1.2	1.1	-1.1	0.3	-0.2	-0.2	-1.3	-0.9
40	-0.1	0.2	-1.1	1.0	-1.2	1.2	-0.4	0.5	-1.0	1.2	-1.2	1.1	-1.1	0.2	-0.2	-0.1	[illegible]	-0.9

GAIN IN GM BY DEBALLASTING (IN FEET)

MEAN DRAFT (FT.)	F.P.	W.T.#1 P&S	[illegible] P&S	L.M.T.#2 P&S	[illegible] P&S	[illegible] P&S	[illegible] P&S	[illegible] P&S	[illegible] P&S	[illegible] P&S	[illegible] P&S	[illegible] P&S	[illegible] P&S	D.C.	AFT D.T.	A.P.	S.T.#1	S.T.#2
30	0.6	1.2	1.9	-0.4	1.9	-0.9	0.6	-0.5	1.7	-0.9	1.9	-0.7	2.4	-0.3	0.9	0.5	2.3	1.4
32	0.5	0.6	1.7	-0.7	1.8	-1.1	0.8	-0.4	1.6	-1.1	1.8	-0.9	2.0	-0.1	0.6	0.4	2.0	1.3
34	0.5	0.5	1.5	-0.8	1.7	-1.2	0.8	-0.6	1.6	-1.2	1.7	-1.0	1.3	-0.1	0.5	0.4	1.9	1.2
36	0.0	-0.2	1.2	-1.2	1.3	-1.5	0.5	-0.7	1.1	-1.5	1.3	-1.3	1.3	-0.2	0.1	0.2	1.3	0.9
38	0.2	-0.2	1.2	-1.7	1.2	-1.4	0.3	-0.6	1.1	-1.4	1.2	-1.2	1.1	-0.2	0.0	0.3	1.3	0.8
40	0.1	-0.3	1.1	-1.3	1.2	-1.5	0.4	-0.6	1.0	-1.5	1.2	-1.4	1.0	-0.2	-0.1	0.2	1.2	0.7

NOTES: 1. THE UPPER TABLE GIVES THE APPROXIMATE GAIN IN GM OBTAINED BY COMPLETELY FILLING ANY BALLAST TANK WHICH IS INITIALLY EMPTY. THE LOWER TABLE GIVES THE APPROXIMATE GAIN IN GM OBTAINED BY COMPLETELY EMPTYING ANY BALLAST TANK WHICH IS INITIALLY FULL. A NEGATIVE NUMBER INDICATES A DECREASE IN GM.

2. ENTER THE APPROPRIATE TABLE AT THE SHIP'S INITIAL DRAFT AND READ THE INCREASE IN GM FOR THE TANK OR TANK PAIR INVOLVED. LINEAR INTERPOLATION BETWEEN THE TABULATED DRAFTS IS PERMISSIBLE.

of minimum GM. Where the older graphs of required GM vs draft displayed only one curve, a *family* of curves is now common, since the average permeability of major blocks of cargo can be drastically changed from voyage to voyage, the sail areas of ships can be changed by loading containers to different heights, and ballast patterns can be varied within extreme limits.

Five presentations are shown here. The weather criterion graph (Figure 13) is clear, covers likely operational conditions, and sources itself (although it does not explain curves' slope discontinuities, which are due to a change of criterion). It would benefit from having the safe/unsafe areas labelled, elementary as this may appear. The curves and the grid are easily distinguished, despite both being solid lines.

The need for explanations of the interplay of criteria responsible for shaping the curves of required GM is greater in the case of Figures 14 and 15. The curves in Figure 14 are physically separate, although crossing at one point, yet they have sensibly been distinguished by dotting and dashing, which helps to separate them from the strong grid used. In Figure 15, unexplained discontinuities (reflecting operational restrictions) can be confusing.

The curves of Figures 16 and 17 come from particularly ambitious T&S booklets. Both show desirable features, but Figure 17 is clearly superior. Where Figure 16 ties instructions to particular curves with arrows, there is no distinction between the curve and the areas, to minimize their interference. Curves 1 and 2 are insufficiently distinguished from the grid and each other. Figure 17, which chooses to focus on allowable KG rather than required GM, has excellent

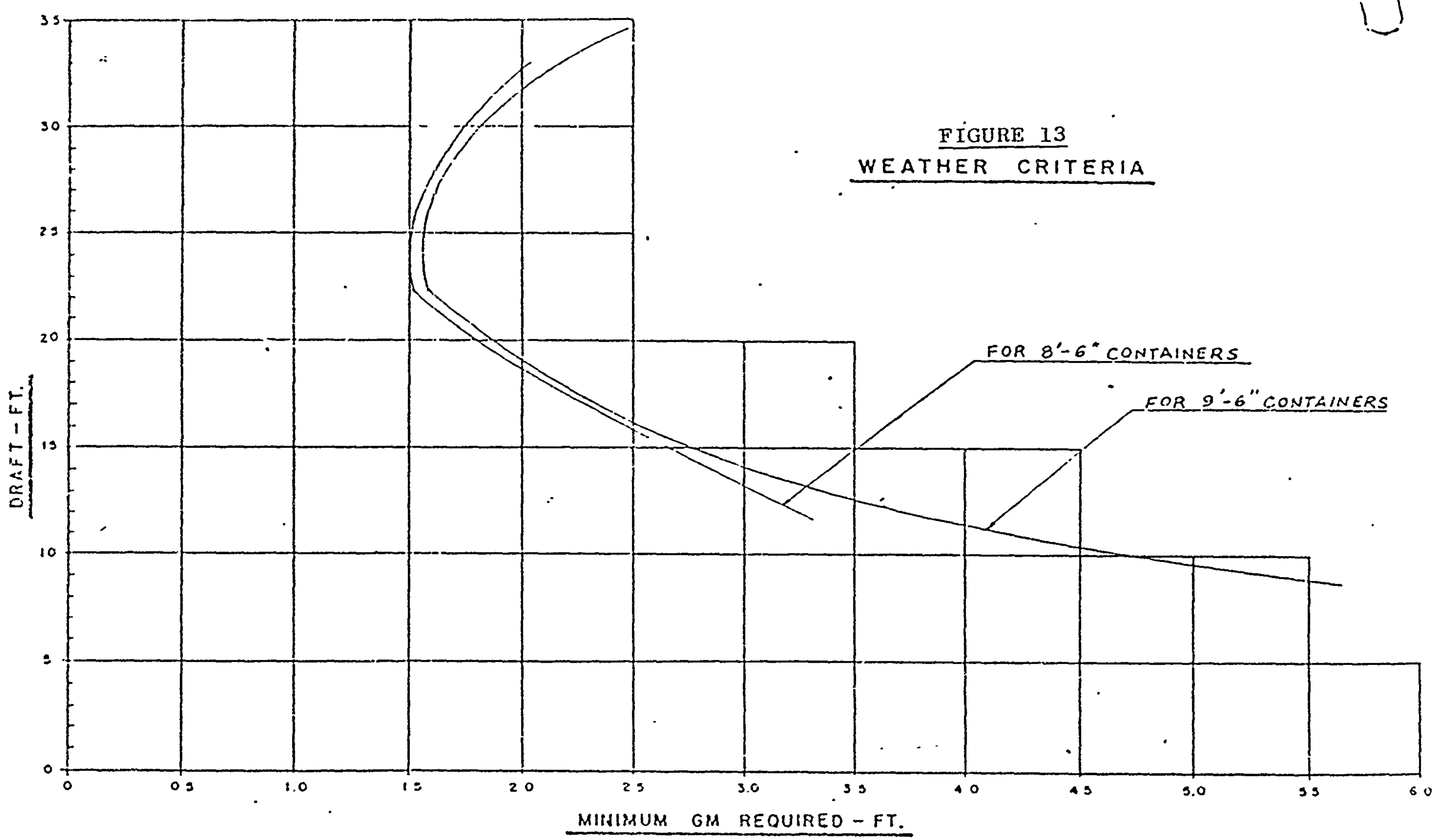


FIGURE 13
WEATHER CRITERIA

NOTE: MINIMUM GM REQUIREMENT HAS BEEN PREPARED FOR 1) 9'-6" CONTAINERS ON DECK STACKED 4 HIGH
2) 8'-6" CONTAINERS ON DECK STACKED 4 HIGH

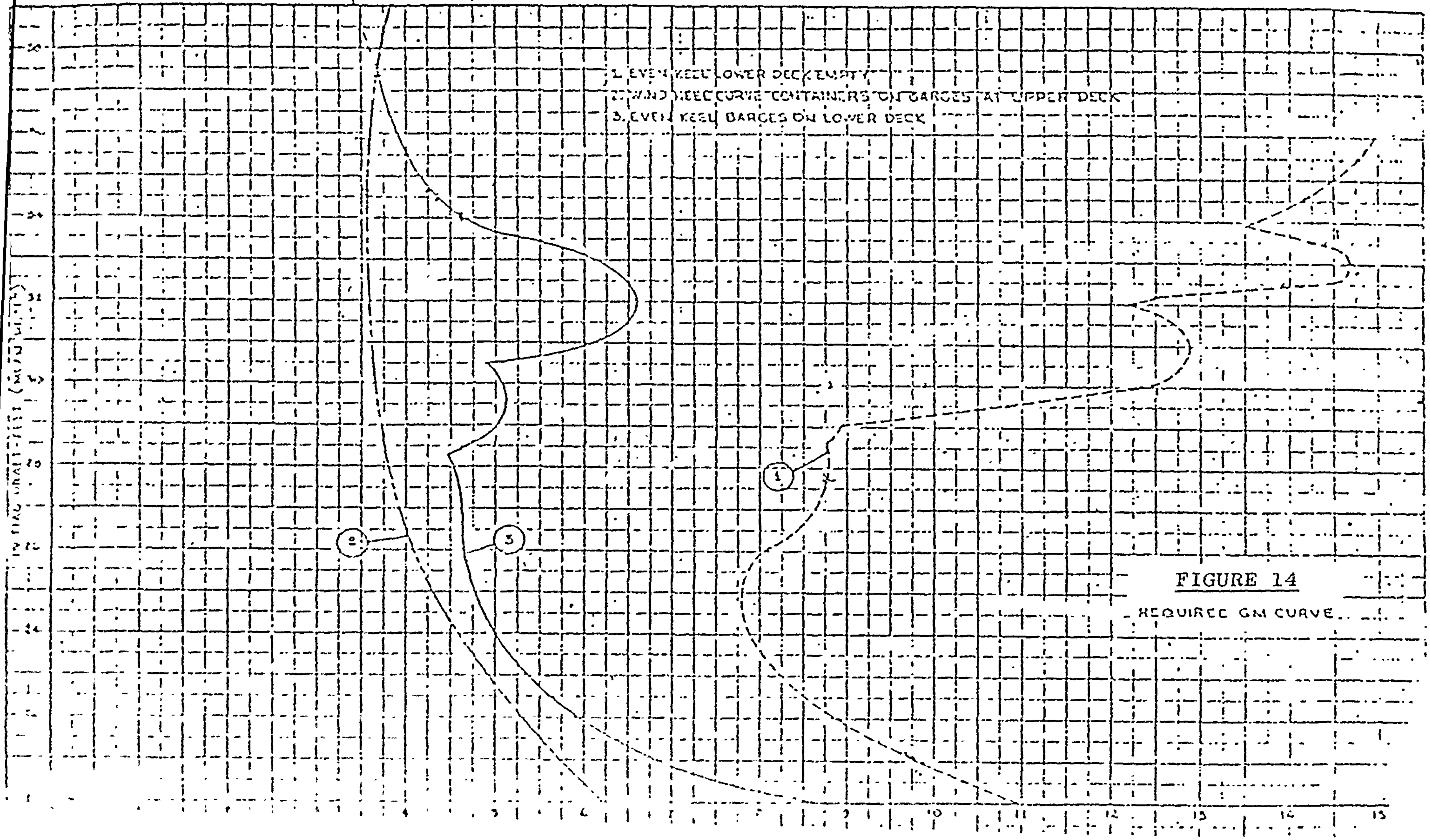


FIGURE 14

REQUIREE GM CURVE

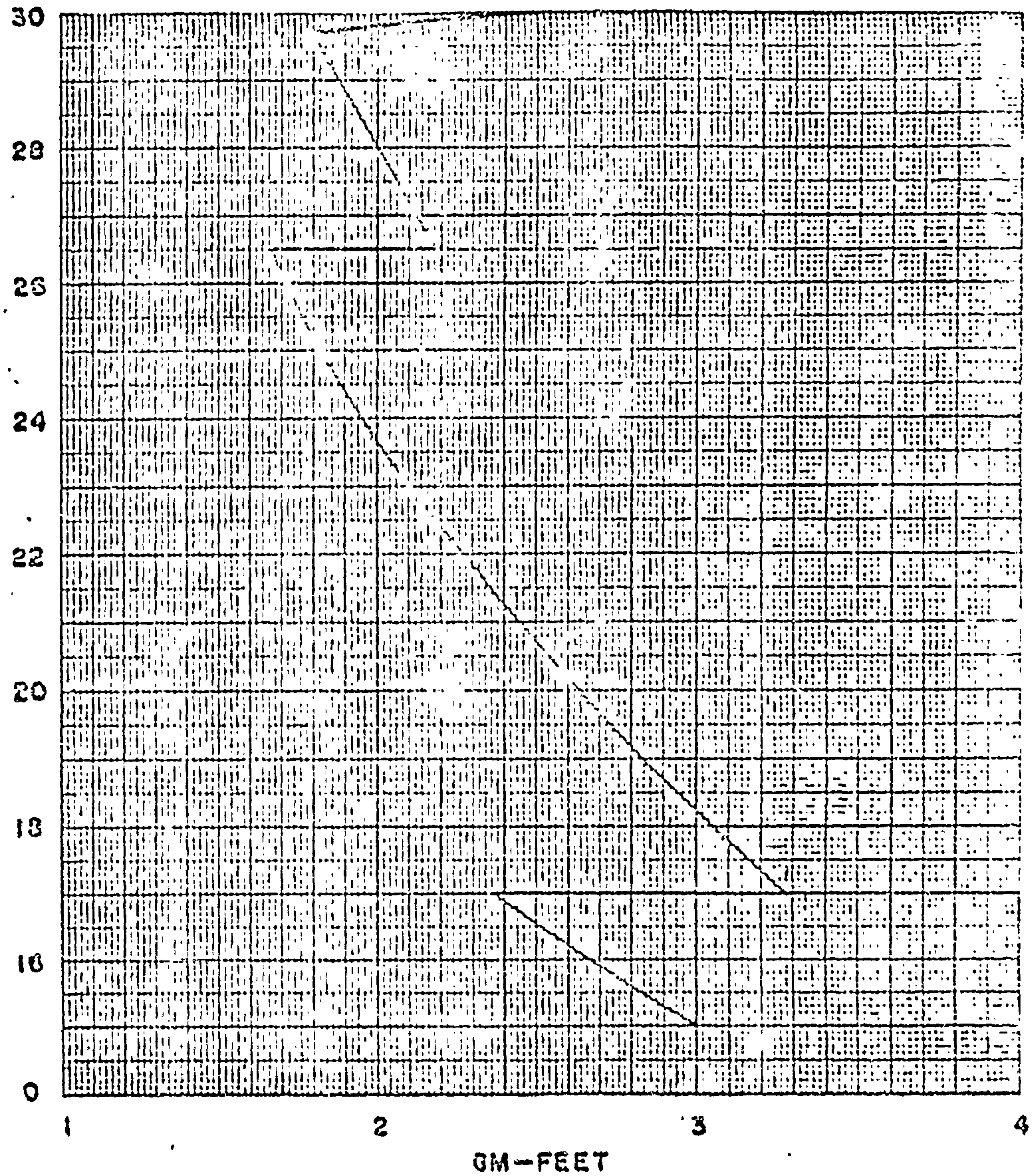


FIGURE 15

Curve of required GM showing unexplained plateaus (see text)

FIGURE 16

REQUIRED GM CURVES

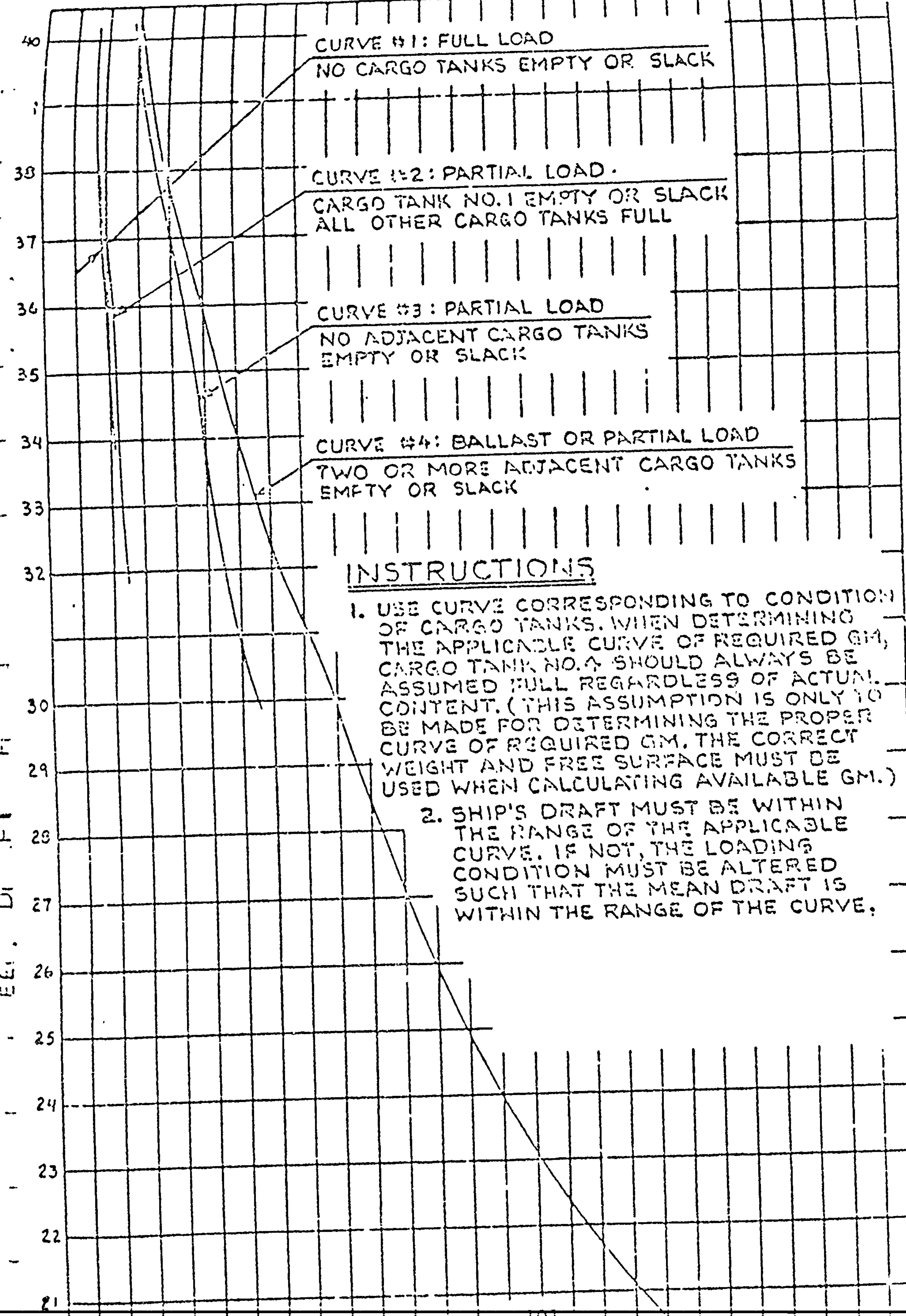
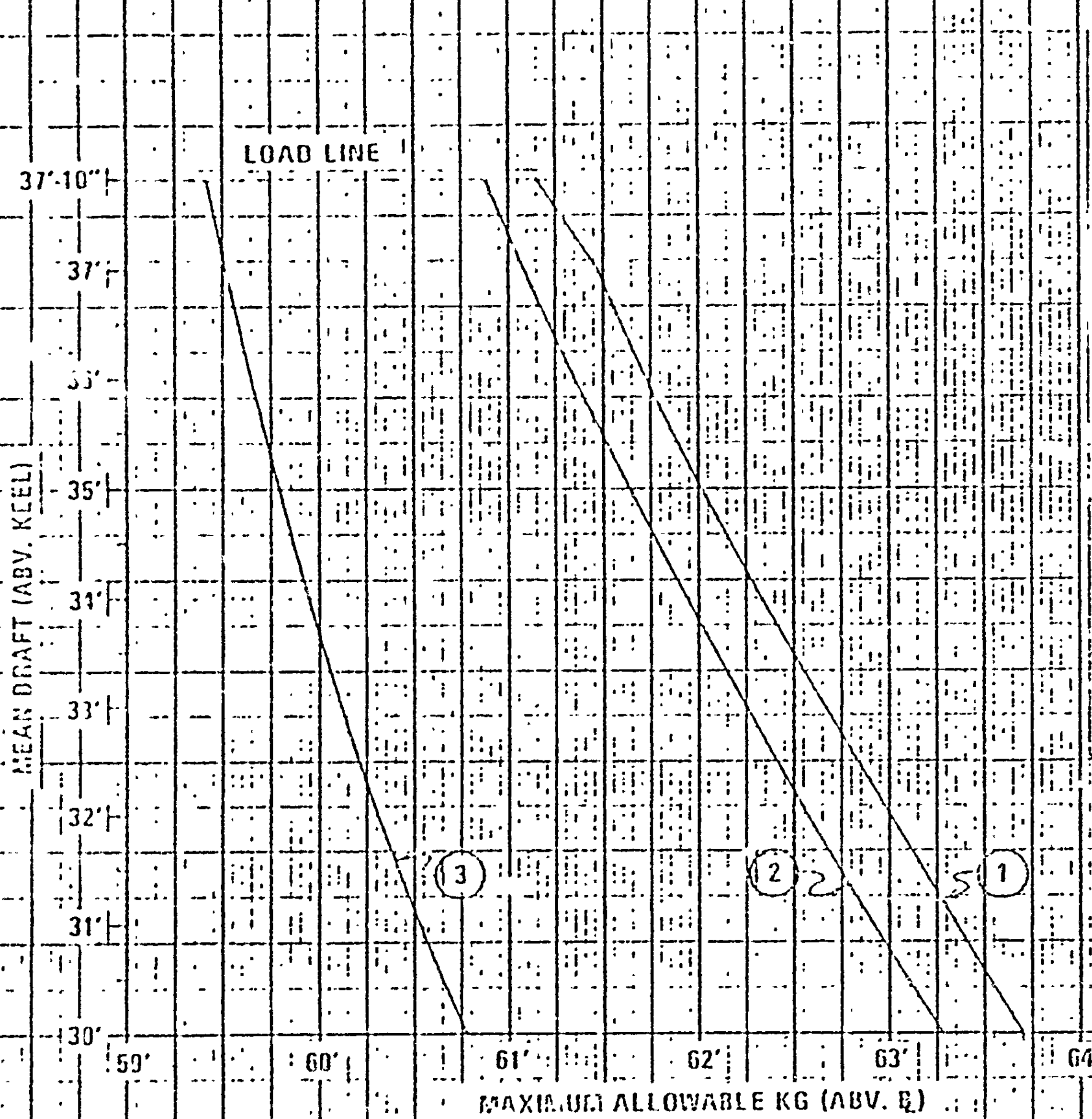


FIGURE 17 MAXIMUM ALLOWABLE KG (CORRECTED FOR FREE SURFACE)



USE CURVE 1 WHEN:

A) <u>ALL</u> CARGO TANKS CONTAIN 8000 TONS OR MORE EACH OF LNG, <u>AND</u>

B) <u>NO</u> BALLAST TANK BETWEEN FRAMES 56 AND 101 IS FILLED ABOVE THE 30' LEVEL, <u>AND</u>

C) THE FULL LOAD STABILIZING TANK, SWB 8 ℄, IS AT OPERATING LEVEL.

USE CURVE 2 WHEN:

A) AND B) SAME AS FOR CURVE 1, <u>AND</u>

C) THE FULL LOAD STABILIZING TANK, SWB 8 ℄, IS EMPTY.

USE CURVE 3 WHEN:

A) <u>ANY</u> CARGO TANK CONTAINS LESS THAN 8000 TONS OF LNG, <u>OR</u>

B) <u>ANY</u> BALLAST TANK BETWEEN FRAMES 56 AND 101 IS FILLED ABOVE THE 30' LEVEL.

lettering, numbering, and instructions. The axes of the graph are referenced and load line draft is shown, the curves cut off at the load line draft, and the grid facilitates interpolation with minimum visual interference. The instructions on Figure 17 are more complex than those on Figure 16, but are one-stage, and are prominent enough to ensure that they will be read before the table is used. The governing stability criterion may be displayed in the form of curves of limiting values of GM or KG . VCG and vertical moments are already familiar to U.S. mariners, in the form of ABS or regulatory body assigned curves of VCG (Figure 18) or as privately developed tables (see example, Figure 19, developed by Captain Waldo). With either of these tables and his knowledge of the present disposition of ballast, stores, and fuel, the ship's officer could inform the terminal of the maximum permissible amount for the cargo and thereby participate in the prestow planning process. An additional maximum table of deadweight moment would be even simpler.

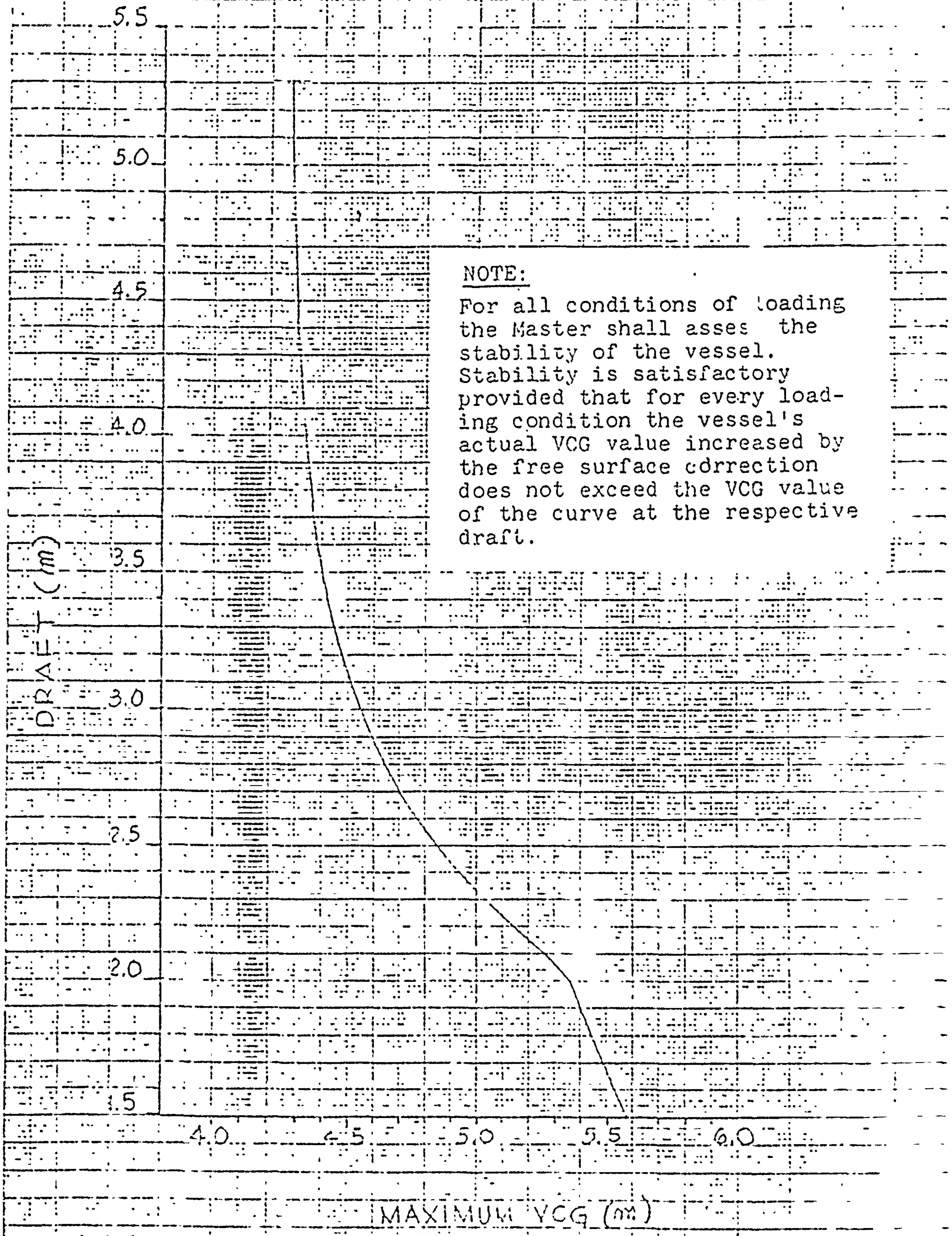
4.1.7 Tank Capacities and Centers

The information typically given for tanks includes the weight and cubic contents of the tank, centers of gravity, and vertical moment of free surface. The latter is usually in two columns, giving "slack" and "98% full-5° heel" free surface moments. Compartment identifications or profile plans are often included with the capacities table.

Two types of compartment capacity tables, Tables 25 and 26, are reproduced to illustrate typical layout. An alternative (Table 27) tabulation of ballast wing tanks' properties shows some consideration for the user's

FIGURE 18

MAXIMUM VCG vs. DRAFT[1]

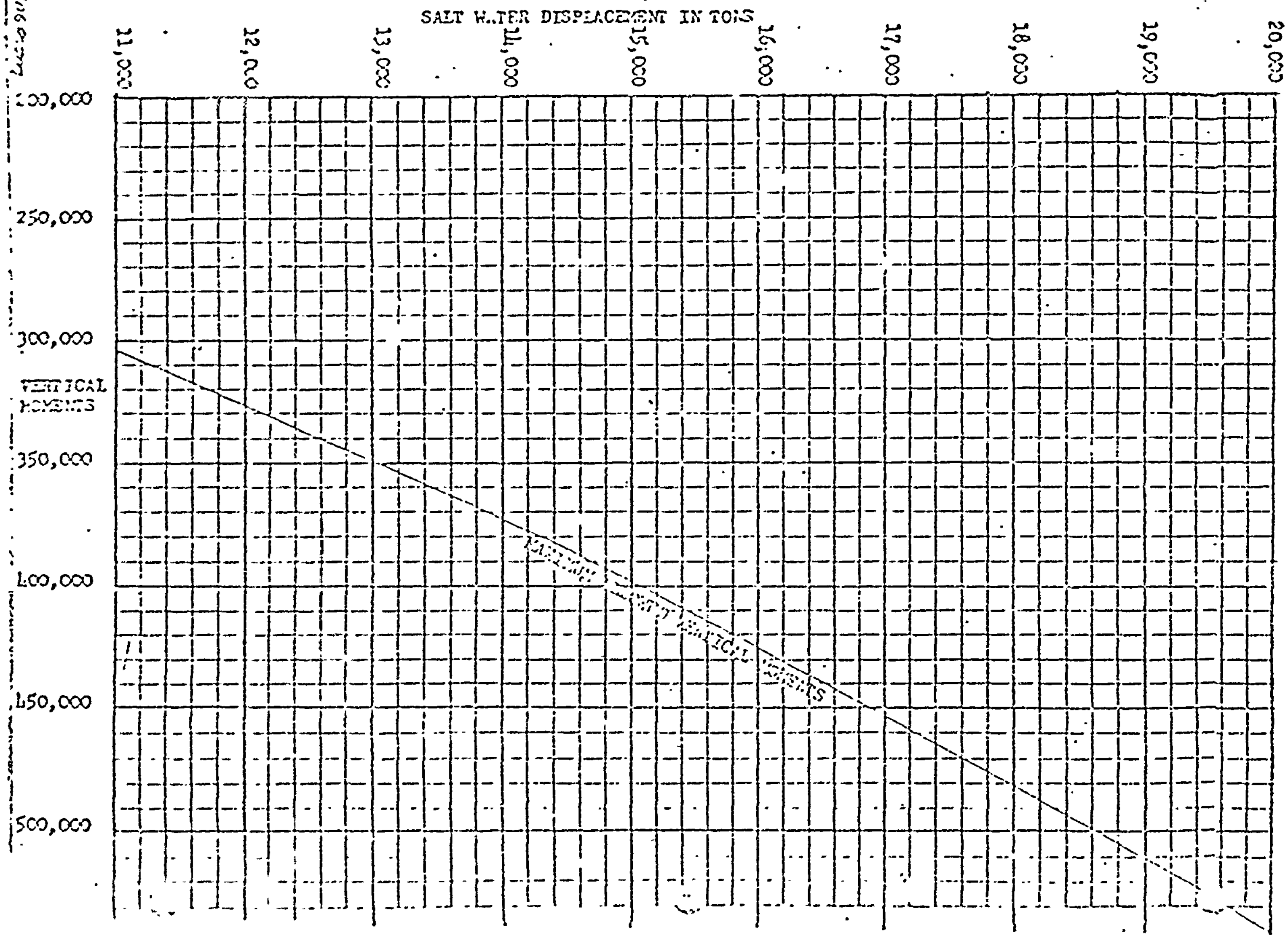


151.

[1] Source: ABS

FIGURE 19 GRAPH OF MAXIMUM ALLOWED VERTICAL MOMENTS

GRAPH DRAWN BY CAPT. W. H. WALDO FROM INFORMATION GIVEN IN CURVE OF TONS PLAN, CAPACITY PLAN RECEIVED 4/30/70 AND STABILITY BOOKLET RECEIVED 4/30/70.



Master or Chief Mate will dr two red lines showing vessel lightship operational displ in tons including fuel, wate ballast, stores but not incl cargo, and the corresponding vertical moments for the est imated departure condition.

A copy of this graph will be given to the Marine Mgr o other person loading the ve who then may add his estimat weight of cargo to vessels to find total displacement tons. The estimated vertic moments of the cargo can be added to vertical moments o the vessel to find total VM Quick reference to the grap will disclose if the VM is above the maximum allowed.

TANK CAPACITIES AND FREE SURFACE DATA

TABLE 25

	(* = EPOXY COATED) TANK	FRAME	100% VOL. GALS.	100% CAP. L.TONS	VCG (KEEL BOT) @100%	LCG (⊠) A+/F-	SLACK FR.SURF. FT-TONS	98%-5° FR.SURF. FT-TONS
SALT WATER BALLAST	FOREPEAK	0-22	176697	674.94	37.01	-342.27	4187	—
	#1P *	28-34	151343	578.00	19.16	-251.96	2459	—
	#1S *	28-34	152006	580.62	19.12	-251.96	2459	—
	#2 ℄ *	34-40	338363	1292.45	17.07	-206.54	6504	—
	#2P	34-40	106,147	405.45	31.91	-203.67	618	.
	#2S	34-40	105525	403.07	32.03	-203.79	618	—
	#3P *	40-46	205973	786.78	29.54	-156.87	1702	—
	#3S *	40-46	205075	783.33	29.63	-156.94	1702	—
	#4P	46-52	183850	702.25	22.97	-108.84	757	—
	#4S	46-52	182947	698.80	23.04	-108.82	757	—
	#5P	52-58	383469	1464.74	25.09	-60.70	3868	—
	#5S	52-58	381440	1456.99	25.17	-60.75	3868	—
	#6P *	58-64	443627	1694.53	23.81	-12.25	4155	—
	#6S *	58-64	440875	1684.01	23.82	-12.30	4155	—
	#7P	64-67	236711	904.17	23.39	+23.88	2162	—
	#7S	64-67	236711	904.17	23.39	+23.88	2162	—
	#8 ℄	84-88	230910	882.01	19.73	+190.21	4534	—
	#8P *	84-88	434445	1661.36	26.60	+181.77	4372	—
	#8S *	84-88	433138	1654.46	26.68	+181.75	4372	—
	#9 ℄	88-94	306274	1169.95	22.03	+230.14	6801	—
	#9P	88-94	414459	1590.75	33.06	+230.98	4372	—
	#9S	88-94	414653	1583.85	33.16	+231.00	4372	—
	#10P *	94-99	303692	1160.02	38.19	+274.96	3643	—
	#10S *	94-99	301842	1152.13	38.30	+275.07	3643	—
	#11P *	99-109	339829	1298.05	41.90	+323.55	5694	—
	#11S *	99-109	335937	1283.13	42.12	+323.83	5694	—
	#12P	109-125	293213	1119.99	40.97	+420.82	414	—
	#12S	109-125	293213	1119.99	40.97	+420.82	414	—
			(98%)	(98%)	(@98%)			
FUEL OIL	#3 ℄	40-46	391330	1405.23	15.78	-158.10	6399	3846
	#4 ℄	46-52	417377	1498.76	15.34	-110.05	6399	[illegible]
	#5 ℄	52-58	427837	1536.33	15.42	-61.48	6399	3846
	#6 ℄	58-64	433697	1557.37	15.65	-12.74	6399	[illegible]
	OVERFLOW P	76-81	37321	134.02	3.43	+128.19	1954	353
	SLUDGE *	76-79	37112	133.27	3.00	+121.10	3200	4?8
			(100%)	(100%)	(@100%)			
FRESH WAT.	POT. WAT. ℄	64-67	[illegible]	367.41	17.08	-23.92	1507	--
	RES. FEED P	70-75	35183	130.66	3.10	+90.69	687	—
	RES. FEED S	70-75	[illegible]	130.66	3.10	+90.69	687	—
	DISTILLED ℄	[illegible]	[illegible]	69.35	44.15	+1??.57	26	—
	SEWAGE ℄	96-97	[illegible]	[illegible]	32.07	-10?.94	274	—
			(0° LVL.)	(0° LVL.)	(@0° LVL.)			
	ROLL STAB.	67-70	[illegible]	775.65	12.59	+47.64	60170	—

TABLE 26 COMPARTMENT CAPACITIES

TANK	CAP L TONS	WEIGHT L. TONS	VCG ABOVE ℄ (FEET)	VERT MOMENT (FT-TONS)	LCG FROM FP (FEET)	LONGL MOMENT (FT-TONS)	VERT. MOM. OF FS FT. TONS SLACK	98% FULL
S. W. BALLAST TANKS								
No.1 Double Bottom P	168.3		2.7		131.9		1599	
No.1 Double Bottom S	168.3		2.7		131.9		1599	
No.2 Double Bottom CL	459.1		2.4		204.1		11568	
No.2 Double Bottom P	147.7		2.7		209.6		865	
No.2 Double Bottom S	147.7		2.7		209.6		865	
No.3 Double Bottom CL	472.7		2.5		303.0		12473	
No.3 Double Bottom P	239.6		2.6		304.3		2083	
No.3 Double Bottom S	239.6		2.6		304.3		2083	
No.4 Double Bottom CL	483.0		2.5		394.0		12481	
No.4 Double Bottom P	223.3		2.6		391.1		1809	
No.4 Double Bottom S	223.3		2.6		391.1		1809	
No.5 Double Bottom P	100.2		2.7		543.0		639	
No.5 Double Bottom S	100.2		2.7		543.0		639	
M1 Double Bottom P	108.0		2.7		480.9		780	
M1 Double Bottom S	108.0		2.7		480.9		780	
Fore Peak	154.9		29.4		28.7		304	
Aft Peak	252.4		30.5		645.6		3092	
Total	3902.8							
FUEL OIL TANKS								
No.1 Deep Tank (D.O.)	138.3		18.0		48.3		163	153
No.2 Deep Tank P	182.9		18.3		66.8		110	103
No.2 Deep Tank S	182.9		18.3		66.8		110	103
No.3 Wing Tank P	296.3		26.0		103.8		326	[illegible]
No.3 Wing Tank S	296.3		26.0		103.8		326	[illegible]
No.4 Wing Tank P	346.8		20.3		149.1		1094	563
No.4 Wing Tank S	346.8		20.3		149.1		1094	563
No.5 Deep Tank P	363.0		13.4		544.3		1655	[illegible]
No.5 Deep Tank S	325.6		13.2		544.1		1359	[illegible]
No.6 Deep Tank P	125.6		10.0		592.5		13[illegible]	[illegible]
No.6 Deep Tank S	100.3		11.1		588.4		119	[illegible]
MA Settlers Cntrd. P	183.0		16.7		446.7		224	
MB Settlers Cntrd. S	183.0		16.7		446.7		224	
MC Settlers Cntrd. P	193.9		15.9		446.8		224	

TABLE 27

BALLAST WING TANKS – V.C.G. and FREE SURFACE DATA

1 – PORT OR STBD			
TONS	V.C.G.	FREE SURF.	NOTES
100	7.3'	200	
200	10.7'	530	
300	13.4'	940	
400	15.6'	1380	
500	17.6'	1980	
560	19.0'	2459	
580	19.1'	0	

2 – PORT OR STBD			
TONS	V.C.G.	FREE SURF.	NOTES
100	19.0'	190	
200	22.5'	525	
250	24.2'	335	
300	26.6'	50	
405	31.9'	0	

5 – PORT OR STBD			
TONS	V.C.G.	FREE SURF.	NOTES
100	3.0'	670	
200	5.5'	1100	
300	7.5'	1560	
400	9.0'	2000	
500	10.9'	2400	
600	12.0'	2700	
700	13.5'	2980	
800	14.8'	3220	
900	16.0'	3470	
1000	17.6'	3750	
1125	19.5'	2086	
1300	22.2'	305	
1460	25.1'	0	

6 – PORT OR STBD			
TONS	V.C.G.	FREE SURF.	NOTES
200	4.0'	1900	
300	5.3'	2350	
400	6.6'	2700	
500	8.5'	3130	
600	9.2'	3310	
700	10.5'	3530	
800	11.8'	3700	
900	12.8'	3840	
1000	14.0'	3930	
1100	15.4'	4040	
1340	19.0'	2257	
1400	21.0'	360	
1689	23.8'	0	

potential role as a commentator on the operational use of tanks, but leaves too little room for suggestions as how best to use the various tanks/tank combinations.

The capacities tables always use the CGs of full compartments, rather than intermediate values corresponding to operational conditions. This increases the actual, as opposed to calculated, GM. The practice partially explains the frequency with which vessels sail with GM in excess of that stated. There was no indication, in any of the booklets examined, of the effects of filling or emptying specific compartments on the operation of the vessel. This is true even of deep-wing tanks and 'saddle tanks' which can lead to excessive tenderness and localized sagging if not employed with discretion.

A table of capacities and centers of gravity (longitudinal, vertical, and transverse) should be provided for *every* compartment available for the carriage of cargo, fuel, stores, feed water, potable water, or water ballast. Tank tables should incorporate any corrections to reflect the location of the sounding pipe/ullage port. Tables or curves giving volume, vertical center of gravity, and free surface correction as a function of liquid level should be included where the tank depth is such that the extent of and manner of change of VCG with depth and/or the type of vessel requires this (e.g. LNG vessels).

4.1.8 Cargo Space and Capacity Data

This component of the T&S booklets has been supplemented, if not superseded by loading manuals. The data in most booklets was poorly presented - either difficult to read (Table 28) or curiously divorced from numerical detail (Figure 20). A more useful compilation of facts is given in Figure 21, but altogether, the fate

TABLE 28

SUMMARY of CAPACITIES & CENTERS

CARGO SPACE	BETWN FRAMES	BALE CARGO CU. FT	VCG ABOVE B.L. FT.	LCG AFT F.P. FT.	[illegible] LBS/SQ FT	CLEAR DECK AREA SQ. FT	CLEAR DECK HEIGHT FT & INS	[illegible]
No 1 MAIN DECK	14-36	-	-	-	360	2645	[illegible]	[illegible]
FLAT DECK	14-36	19218	52 33	53 6	380	2783	6'-11"	[illegible]
2ND DECK	14-36	17240	43 75	53 3	430	1727	7'-7½"	[illegible]
1ST FLAT	14-36	19292	30.65	54.2	[illegible]	1617	15'-2"	[illegible]
TOTAL No 1	14-36	55750	41 95	53.7	-	7672	-	[illegible]
No 2 MAIN DECK	36-55	-	-	-	360	3000	13'-2½"	[illegible]
FLAT DECK	36-55	25328	49 63	98 5	390	3139	6'-11"	[illegible]
2ND DECK	36-55	25085	40 33	99.2	430	2773	7'-7¼"	[illegible]
1ST FLAT	36-55	31167	28.30	99.2	620	2292	10'-6"	[illegible]
2ND FLAT	36-55	16823	17 29	100 [illegible]	[illegible]	2059	6'-11½"	[illegible]
TOTAL No 2	36-55	[illegible]703	35 18	99 3	-	13252	-	[illegible]
No 3 MAIN DECK	55-107	-	-	-	360	8865	13'-2½"	[illegible]
2ND DECK	55-107	147244	42.65	183.8	[illegible]	7239	12'-8¼"	[illegible]
1ST FLAT	55-107	96399	27.72	188.9	560	8737	10'-5¼"	[illegible]
2ND FLAT	55-107	64334	17 06	189 3	400	7463	6'-11½"	[illegible]
TANK TOP	55-107	59256	6.54	171 0	[illegible]	7452	6'-11½"	[illegible]
TOTAL No 3	55-107	367245	28 74	187 4	-	41525	-	[illegible]
No 4 MAIN DECK	128-180	-	-	-	360	8489	13'-6½"	[illegible]
2ND DECK	128-180	135720	43 42	369 9	460	9340	12'-1¼"	[illegible]
1ST FLAT	128-180	89285	24 29	363.0	560	8246	10'-2¼"	[illegible]
2ND FLAT	128-180	56214	12 67	362.1	1530	6755	6'-11½"	[illegible]
TOTAL No 4	128-180	281219	34.01	367.7	-	52555	-	[illegible]
TOTAL EXCLUDING DRIVEWAYS		502917	32 29	230 4	-	95579	-	[illegible]
STERN DRIVEWAY	180-[illegible]	11869	45 18	461 0	560	846	12'-6"	[illegible]
MIDSHIP DRIVEWAY STBD	102-128	14816	52.08	271 5	360	1125	12'-11½"	[illegible]
GRAND TOTAL CARGO SPACES		529602	32.90	234 5	-	97550	-	[illegible]

TANKS	BETWN FRAMES	CAPACITY 100%	CAPACITY 98%	L. TONS FUEL OIL [illegible] 98%	L. TONS S.W. 35 cu ft/t 100%	L. TONS F.W. 36 cu ft/t 100%	V.C.G. ABV B.L. FT.	LCG AFT F.P. FT.	[illegible]
FUEL OIL		BBLS.	BBLS.						[illegible]
SETTLER FWD	133-135	373 7	366	54 7	-	-	9 30	316.3	[illegible]
SETTLER AFT	135-137	377 8	370	55 3	-	-	9 55	327.1	[illegible]
CONTAM FO	137-143	355.4	348	52 [illegible]	-	-	9.79	33[illegible].5	[illegible]
TOTAL FUEL OIL TKS		1106 9	1084	162 0	-	-	9.54	326 8	[illegible]
DEEP TANKS		CU FT	BBLS						[illegible]
No 1 CNTR	6-27	9093	~	-	260 1	252.9	12.29	42 9	[illegible]
2 CNTR	27-36	11565	~	-	330 5	321 3	12 21	65 5	[illegible]
3 CNTR	36-55	13704	~	-	391 5	380 6	7.25	91.0	[illegible]
4 P&S	55-55	10138	1775	265 4	211 2	283 1	7 20	114 0	[illegible]
5 CNTR	143-155	6150	1073	160 2	175 7	170.8	10 25	357 5	[illegible]
6 CNTR	153-165	3952	690	102 9	112 9	109 8	10 55	383 5	333
7 P&S	183-193	8922	~	-	254 9	247 7	20 57	446 2	[illegible]
TOTAL DEEP TANKS		63574	3541	528 5	1816 7	1766 2	11 25	179 0	[illegible]
DOUBLE BOTTOMS		CU FT	BBLS						[illegible]
No 3 INBD P&S	55-79	8184	1428	213 0	233 6	227 1	2 45	152 9	[illegible]
3 OUTBD P&S	55-79	6226	1087	162 2	178 0	173 1	2 80	156.9	[illegible]
SUB-TOT No 3	55-79	14410	2515	375 2	41[illegible]	400.2	2.60	154 6	[illegible]
No 4 INBD P&S	79-107	9758	1703	254 4	279 0	271	2 47	217 2	[illegible]
4 FOUTBD P&S	79-93	5734	1001	149 4	163 8	159 6	2 74	200.5	[illegible]
4A OUTBD P&S	93-107	[illegible]	1077	160 [illegible]	176 0	171 1	2 72	234 6	[illegible]
SUB-TOT No 4	79-107	21602	3781	564 4	618 8	601 5	2 61	217.7	[illegible]
MACHY INBD P&S	107-123	6863	1198	178 8	196 2	190 7	2 49	277 1	[illegible]
OUTBD P&S	107-123	7092	1236	184 6	202 4	196 8	2 81	274.7	[illegible]
SUB-TOT MACHY	107-123	13955	2436	363 4	398 6	387 5	2 65	275 9	[illegible]
No 5 FCNTR	123-139	4020	702	104 7	114 8	111 6	2 58	318 8	[illegible]
5F OUTBD P&S	23-139	2521	440	65.8	72 0	70.0	3.56	318 1	[illegible]
5A P&S	39-55	6520	1138	169 8	186 2	181 0	3.27	350 [illegible]	[illegible]
SUB-TOT No 5	23-55	13061	2280	340 3	373 0	362 [illegible]	3.11	334 5	[illegible]
No 6 CNTR	55-180	3[illegible]	553	82 6	90 5	88 0	4 08	392 [illegible]	[illegible]
TOTAL DOUBLE BOTTOMS		66254	11565	1725 7	1892 5	1839.8	2 [illegible]	247 [illegible]	[illegible]
PEAK TANKS		CU FT							[illegible]
FOREPEAK	0-6	3480	-	-	99 4	96 6	15.00	18.2	[illegible]
AFT PEAK	193-[illegible]	2128	-	-	60 8	59.1	22 [illegible]	469.2	[illegible]
TOTAL PEAK TKS		5608	-	-	160 2	155 7	17 92	129 3	[illegible]
FEED & POT WATER		CU FT							[illegible]
[illegible]	25-29	2307	-	-	-	64 0	40 44	301 8	[illegible]
POT [illegible]	[illegible]	[illegible]	-	-	-	31 [illegible]	42 00	301 8	[illegible]

NOTE: [illegible] 98% [illegible] FREE SURFACE VALUE FOR [illegible] SUCH TANKS, EXCEPT WHERE SPECIFICALLY [illegible] OTHERWISE.

VESSEL FIGURE 20	CONTAINER CARGO CAPACITY DATA	PAGE 14

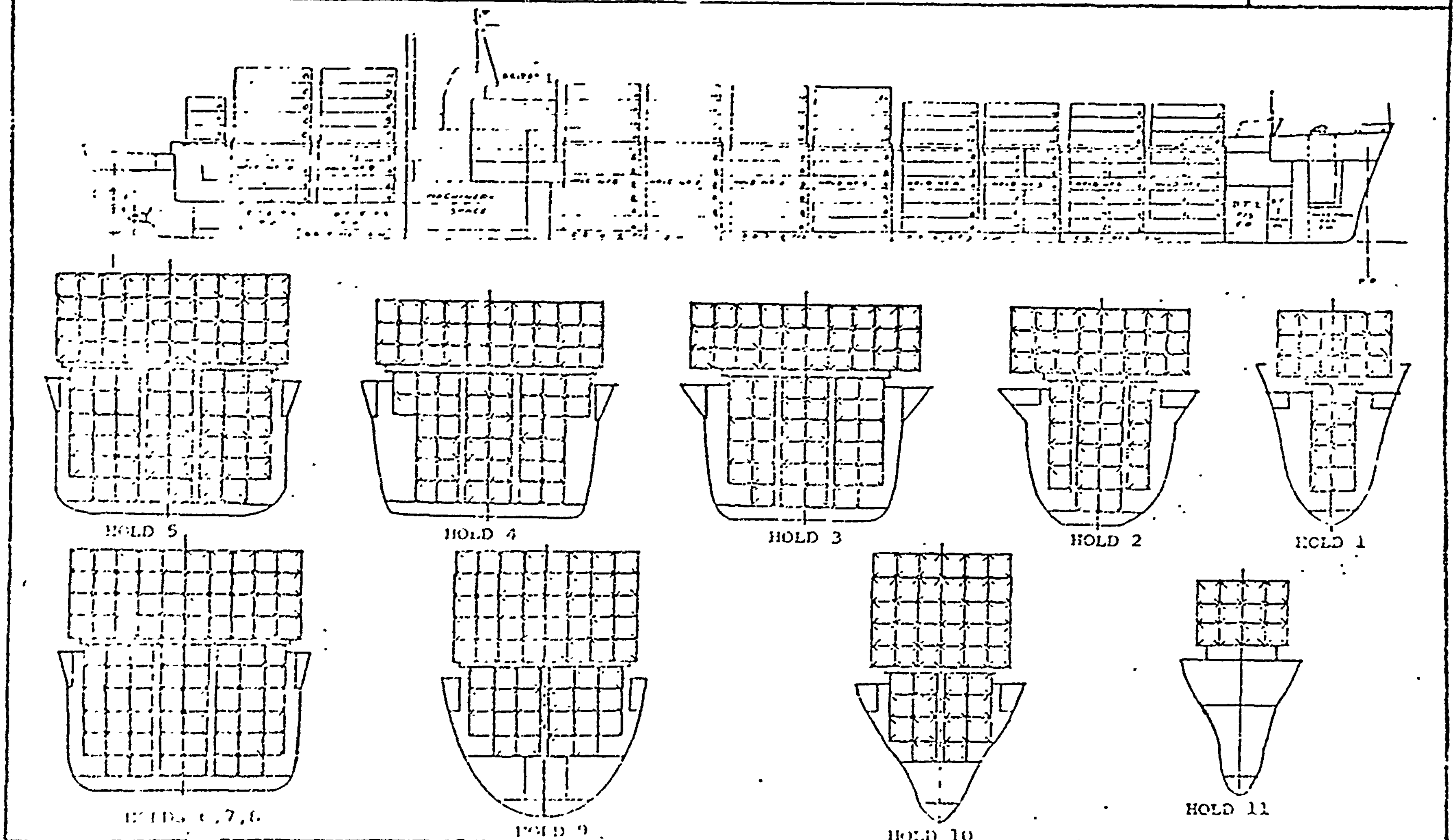
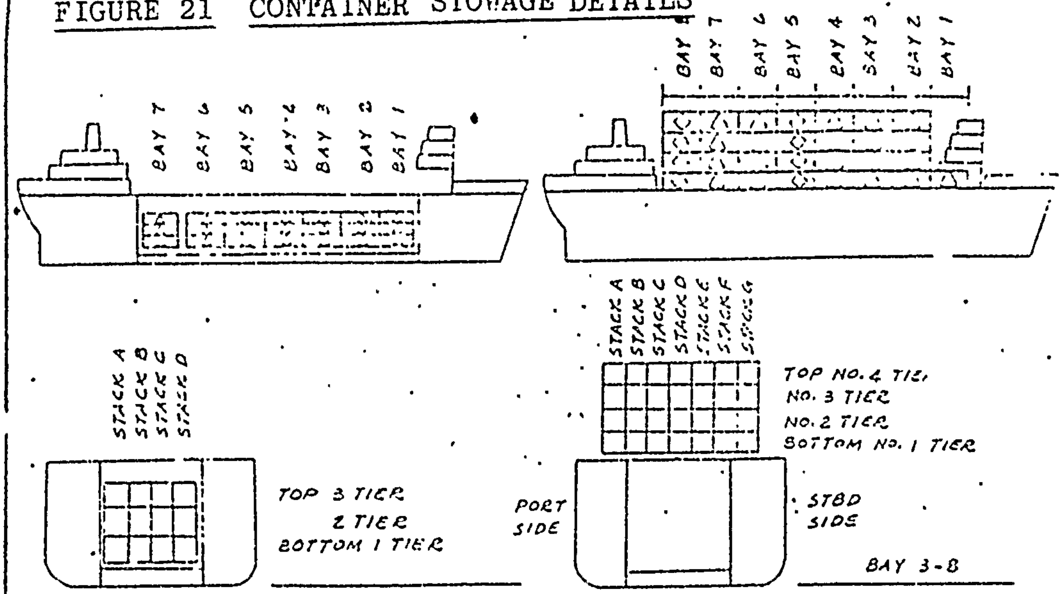
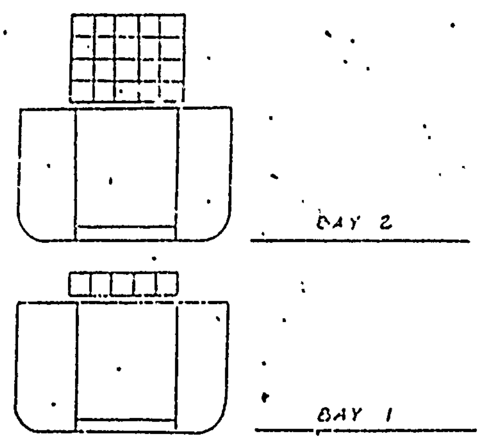


FIGURE 21 CONTAINER STOWAGE DETAILS



CARGO STOWAGE		
CARGO.	REFRIGERATED CONTAINER ◇ 40'-8'-8.6"/9.6'	DRY CARGO CONTAINER △ 40'-8'-8.6"/9.6"
UPPER DECK	56	137
HOLD	—	84
QUANTITY TOTAL	56	221



CONTAINER	TIER	NO OF CONTAINERS	V.C.G. ABOVE BASELINE	
			[illegible]	[illegible]
UPPER DECK	4	47	72.5	76.0
	3	47	64.0	66.5
	2	47	5? 5	57.0
	1	52	47.0	47.5
SUB TOTAL		193		
HOLD	3	28	27.94	30 44
	2	28	17.44	20.94
	1	28	10.94	11.44
SUB TOTAL		84		

CONTAINER	BAY	NO OF CONTAINERS	L.C.G. FROM A.P. FOR [illegible]
UPPER DECK	1	5	[illegible]
	2	20	[illegible]
	3	25	366.7
	4	28	305.1
	5	28	[illegible]
	6	28	[illegible]
	7	28	173.6
	8	25	[illegible]
SUB TOTAL		193	
HOLD	1	12	[illegible]
	2	12	[illegible]
	3	12	317 3
	4	12	272.9
	5	12	[illegible]
	6	12	185.1
	7	12	144.4
SUB TOTAL		84	

and design of this component can only be decided in the context of the whole function of T&S booklets and the relationship between booklet and loading manual.

For barge carriers and containerships, a stowage plan should be included in the booklet, showing the disposition and identification of cargo units. The barge/container size and maximum allowable height in cell/tier should be clearly stated. When the complexity of the vessel makes it difficult to label the plan clearly, some of the information can be tabularized separately and noted by reference.

A suggested presentation of container cargo capacity data is shown in Figure 22, which incorporates these suggestions and could be further improved by printing of CG figures.

4.1.9 Details of Lightship Condition and Summary of Fixed Ballast

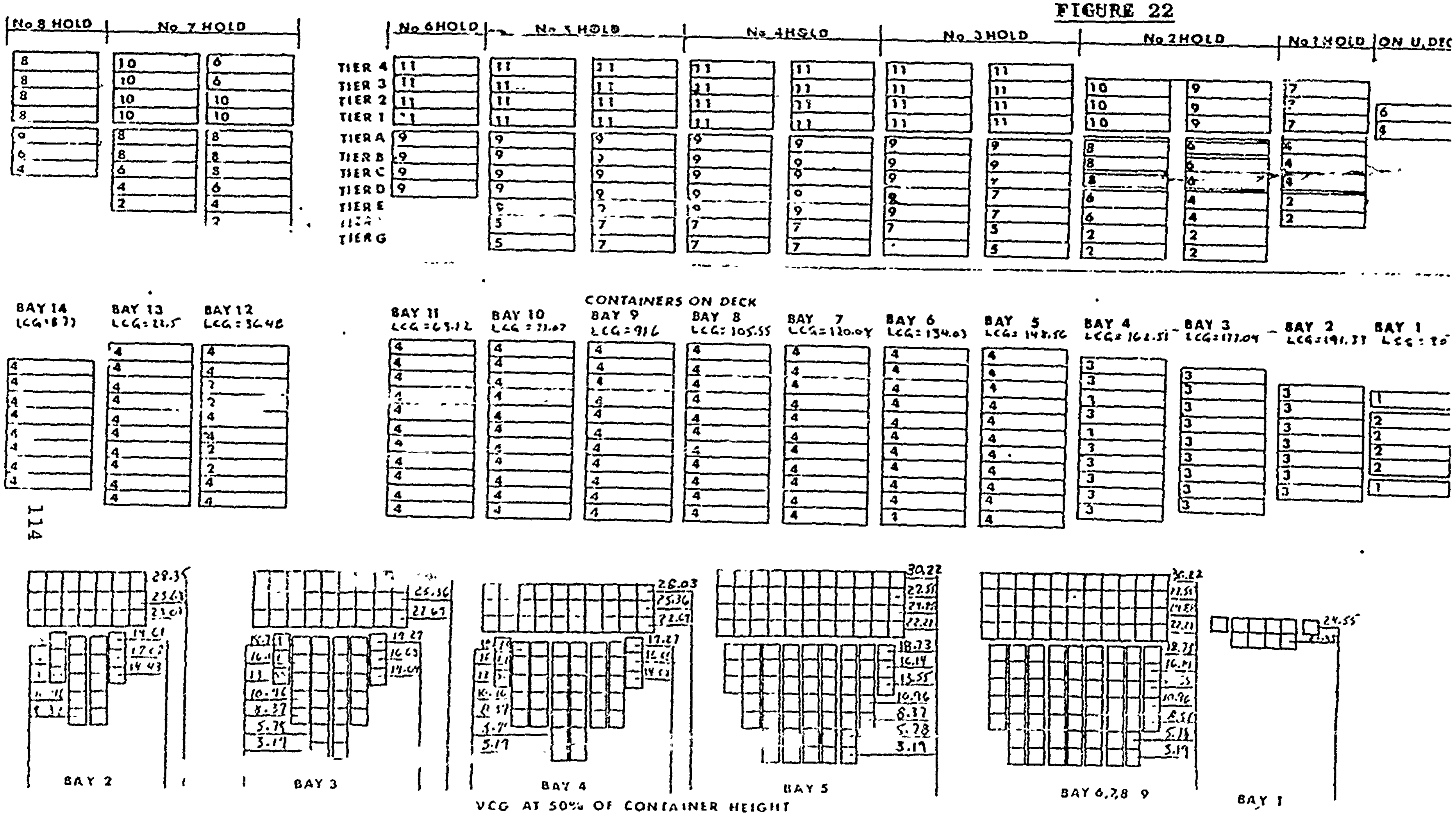
Knowledge of lightship CG and weight is fundamental to the calculation of loaded stability conditions, and for this reason is probably best dealt with by a brief note under principal characteristics and by overprinting calculation forms where appropriate. The separate note, overleaf, which requires further references, is an unacceptable treatment. As lightship details and fixed ballast are virtually permanent, they should be preprinted on stability calculation forms.

The concept of "effective lightship" (Table 29) incorporating weight of crew, stores, fixed ballast, minor and relatively invariant tankage, is used by some operators and many individuals to minimize arithmetic work in the T&S calculations.

CONTAINER STOWAGE PLAN

V.C.G. AT 50% OF THE HEIGHT OF EACH CONTAINER

FIGURE 22



REMARK
ALL CENTERS OF GRAVITY ARE FOR 40'X 8'X 8.5' OR 20'X8'X 8 CONTAINERS AS NOTED

" Lightship Characteristics

The light ship displacement and longitudinal centers of gravity given on Page No. 4 are from the Deadweight experiment conducted on the
on

The vertical center of gravity is from the Inclining experiment conducted on the

These are the official values for the vessel.

Fixed ballast of the U.S. Steel "QCM" Concentrate capped with concrete layer was installed, for the total 2085 Long Tons and is distribute' throughout the hold; VCG of ballast is 9.00 feet above B/L; and

LCG is 314.02 feet aft of F. P.
For details on distribution, see Inclining Data.

The Permanent ballast in this ship is not to be removed or moved without the permission of the United States Coast Guard."

TABLE 29

V. EFFECTIVE LIGHT SHIP

For Stability calculations the following weights are considered constant:

	WEIGHT	VCG	V. MOMENT	LCG	L. MOMENT
*Light Ship	11,765	36.30	427,041	38.90A	457,700A
Lube Oil	124	38.34	4,763	287.56A	35,724A
Potable Water	98	33.78	3,312	183.65A	18,006A
Distilled Water	160	38.12	6,090	287.36A	45,905A
Crew & Effects	10	75.00	750	100.0A	1,000A
Stores	75	47.00	3,525	271.50A	20,350A
FULL SLACK FREE SURFACE:					
Lube Oil	-	-	632	-	-
Potable Water	-	-	66	-	-
Distilled Water	-	-	920	-	-
98% - 5° FREE SURFACE:					
W.T. #2 B P/S	-	-	288	-	-
W.T. #4 A P/S	-	-	446	-	-
W.T. #4 B P/S	-	-	298	-	-
EFFECTIVE LIGHT SHIP	12,232	36.64	448,131	47.31A	578,685A

*Obtained from the results of inclining experiment held on
on . inclining experiment
was held on with the following results: Light Ship - 11,740 long tons, VCG - 36.27', LCG - 40.12' aft mid ships. For simplicity, the values obtained for the are used herein.

Light ship revised for addition of 40' container stowage (See Report of

4.1.10 <u>Sample Loading Conditions</u>

MarAd requires nine sample loading conditions to be incorporated in the T&S booklets for subsidized vessels (see Design Letter No. 3): 0, 10, 50% cargo with 0, 10, 50% consumables. The minimum USCG required number of conditions (Enclosure (1) to NVIC 3-73, Appendix 1) is four - 100% cargo with 10 and 100% consumables, and ballast with 0 and 100% consumables. Owners required numerous additional cargo loadings.

There has been a proliferation of sample loading conditions in recent books. Officers with weak backgrounds in trim and stability calculation may be tempted to search for a matching condition, rather than using the sample loading conditions as guides to the use of the calculation forms. It is suggested that the existing requirements be retained for design purposes, but that teaching considerations govern the choice of examples for inclusion in the booklet. The conditions should be clearly worked and fully explained so that future calculations can be confidently done, from raw data.

Different categories of ships require varying numbers of conditions. These should be kept to a minimum necessary to illustrate the operating principles of the vessel. Ballast and *typical* service conditions should appear. A homogenous cargo condition where summer draft is assumed, for example, is inappropriate for vessels which are volume limited, for example, a tanker which cannot load to her marks carrying light crude. The examples should relate specifically to the cargoes for which the vessel is designed. Other conditions relating to the range of potential cargoes should be included only where there is a possibility of such alternative employment such as grain loads in a tank vessel.

The IMCO requirements for presentation of standard conditions of loading are worth consideration. They prescribe that each example shall include:[1]

1. a small-scale profile of the ship, and where applicable, a plan view diagram, showing distribution of all components of the deadweight
2. a calculation showing lightweight, the distribution and weight of all components of the deadweight, their longitudinal and vertical centers of gravity, longitudinal and vertical weight moments, giving in answer the displacement and positions of longitudinal and vertical centers of gravity corresponding to the appropriate condition. The free surface effects are to be clearly indicated.
3. a summary of the appropriate condition showing the mean draft, displacement, longitudinal and vertical centers of buoyancy and gravity, trimming moment, moment to change trim one inch, trim calculation, draft at after and forward perpendiculars, and - if necessary - draft in way of draft marks.
4. a summary of initial stability, including calculation of GM with and without free surface effects.

4.1.11 Damaged Stability

The topic of damaged stability was raised primarily in the booklets for vessels carrying hazardous cargo,

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[1] Source: Interpretation LL.45, Presentation of Information (Regulation 10(2)). International Association of Classification Societies.

such as LNG. The attached examples, Tables 30 - 32, are representative of the content of the damaged stability section, which at present merely confirms that the vessel meets or exceeds the damaged stability requirements of 46 CFR §153.32 and 34 when operated in conformity with the instructions of the booklet. Such information appears to serve little purpose, since it does not offer 'practical guidance', i.e. tell the master what he can do and suggest or order priorities. The curves of required GM already incorporate the damaged stability considerations for their respective drafts, and detailed knowledge of survivable damage.

An alternative presentation of damaged stability is the graph of required damaged stability GM (Table 31). This has relatively complex instructions, which assume some sophisticated knowledge of stability.

4.1.12 Other Components

Draft marks are often not located at the perpendiculars, and there is a need to correct the calculated drafts in order to obtain the draft at the marks and verify its compliance with legal requirements. Two depictions of draft mark locations are shown here. The clearly labelled profile (Figure 23) is immediately intelligible, and can only be criticized on the niggling grounds that the figures are somewhat illegible. Contrast the schemati diagram, Figure 24. There is unnecessary information on this diagram, it is labelled in a mixture of types and hand-lettering, and altogether more effort is required to extract information. No booklet gave instructions for use of the draft mark location diagram.

Some ships' navigational drafts are different from their forward and after drafts. This can be due to appendages which project below the keel, or to the excess

TABLE 30

SPECIMEN DAMAGE STABILITY INFORMATION

(i)

THE VESSEL HAS BEEN REVIEWED FOR DAMAGE STABILITY ASSUMING THE FOLLOWING EXTENT OF DAMAGE OCCURRING ANYWHERE ALONG THE VESSEL'S LENGTH:

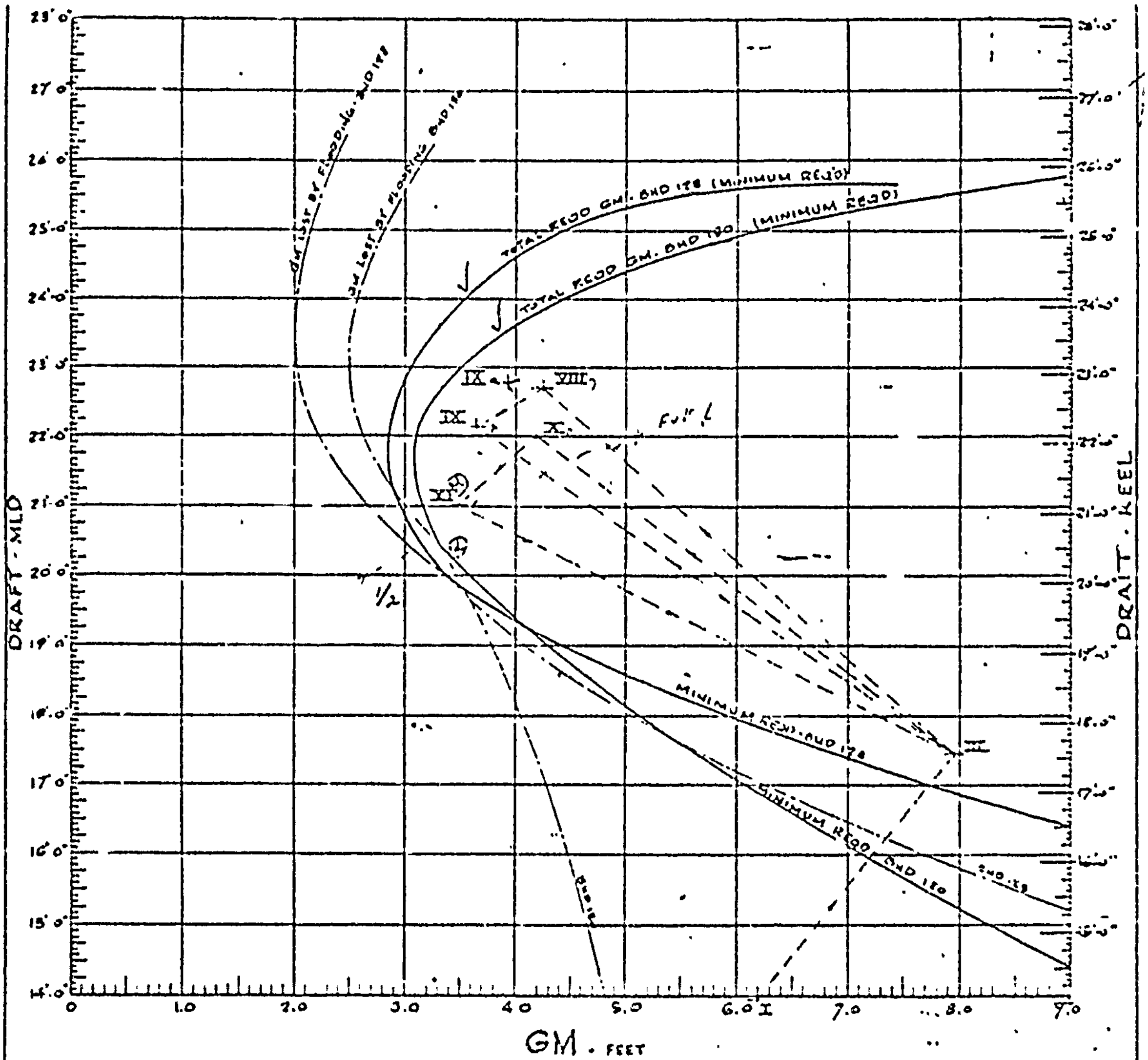
LONGITUDINAL EXTENT	46'-8"
TRANSVERSE PENETRATION	27'-0"
VERTICAL EXTENT	FROM BASELINE UPWARDS WITHOUT LIMIT

B) BOTTOM DAMAGE:

LONGITUDINAL EXTENT	46'-8"
TRANSVERSE EXTENT	22'-6"
VERTICAL PENETRATION	6"-7"

WITH THESE ASSUMPTIONS, THE VESSEL HAS BEEN FOUND TO REMAIN AFLOAT IN A SATISFACTORY CONDITION OF EQUILIBRIUM.

TABLE 31



THE ROMAN NUMERALS CORRESPOND TO THE LOADING CONDITIONS GIVEN IN DETAIL ON THE PRECEDING PAGES.

THE LIMIT FOR IMMERSION IS THE MODIFIED MARGIN LINE, I.E., 3" BELOW THE MAIN DECK AT SIDE FROM STEM TO BHD 128 ALL MAIN DECK OPENINGS FROM BHD 128 TO STERN ARE ASSUMED WATERTIGHT, HENCE STERN SUBMERGENCE TO MARGIN LINE AT BHD 128 IS ALLOWED (PER MARAD LETTER [illegible]

HEELING AFTER DAMAGE IS LIMITED TO 15° OR IMMERSION OF THE MARGIN LINE WHICHEVER OCCURS FIRST

THE CONTINUOUS CURVES GIVE THE MINIMUM REQUIRED INTACT GM, EITHER TO LIMIT HEEL DUE TO UNSYMMETRICAL BUOYANCY OR TO MAINTAIN POSITIVE GM AFTER DAMAGE. THE DIFFERENCE BETWEEN THE TOTAL REQUIRED GM AND THE GM LOST DUE TO FLOODING IS THE RESIDUAL GM REQUIRED TO LIMIT HEEL

ALL CALCULATIONS ARE BASED ON DISPLACEMENTS AT EVEN KEEL BEFORE DAMAGE. ACTUAL TRIM LINES AND SHIPS CHARACTERISTICS ARE USED FOR DAMAGED & HEELED CONDITIONS, NO EMPIRICAL FORMULATIONS OR CONSTANTS ARE EMPLOYED. EXTENT OF DAMAGE IS GENERALLY THAT WHICH IS REASONABLE OR GOVERNED BY CONVENTION 75% PERMEABILITY IS ASSUMED IN ALL VEHICLE SPACES

DAMAGE AT EITHER BHD 56 OR BHD 107 IS LESS SEVERE THAN THE GIVEN BHD 128 AND BHD 190 CURVES

DAMAGED STABILITY

VEHICLE LOAD - TWO COMPARTMENT SUBDIVISION

TABLE 32

DAMAGED STABILITY

1. Extent of Damage

   a) Side Penetration

      (1) Longitudinal Extent – 46.50 ft.
      (2) Transverse Extent – 28.70 ft.
      (3) Vertical Extent – Baseline upward without limit

   b) Bottom Penetration – Forward 0.3 Length

      (1) Longitudinal Extent – 46.50 ft.
      (2) Transverse Extent – 23.92 ft.
      (3) Vertical Extent – 6.56 ft.

   c) Bottom Penetration – Aft 0.7 Length

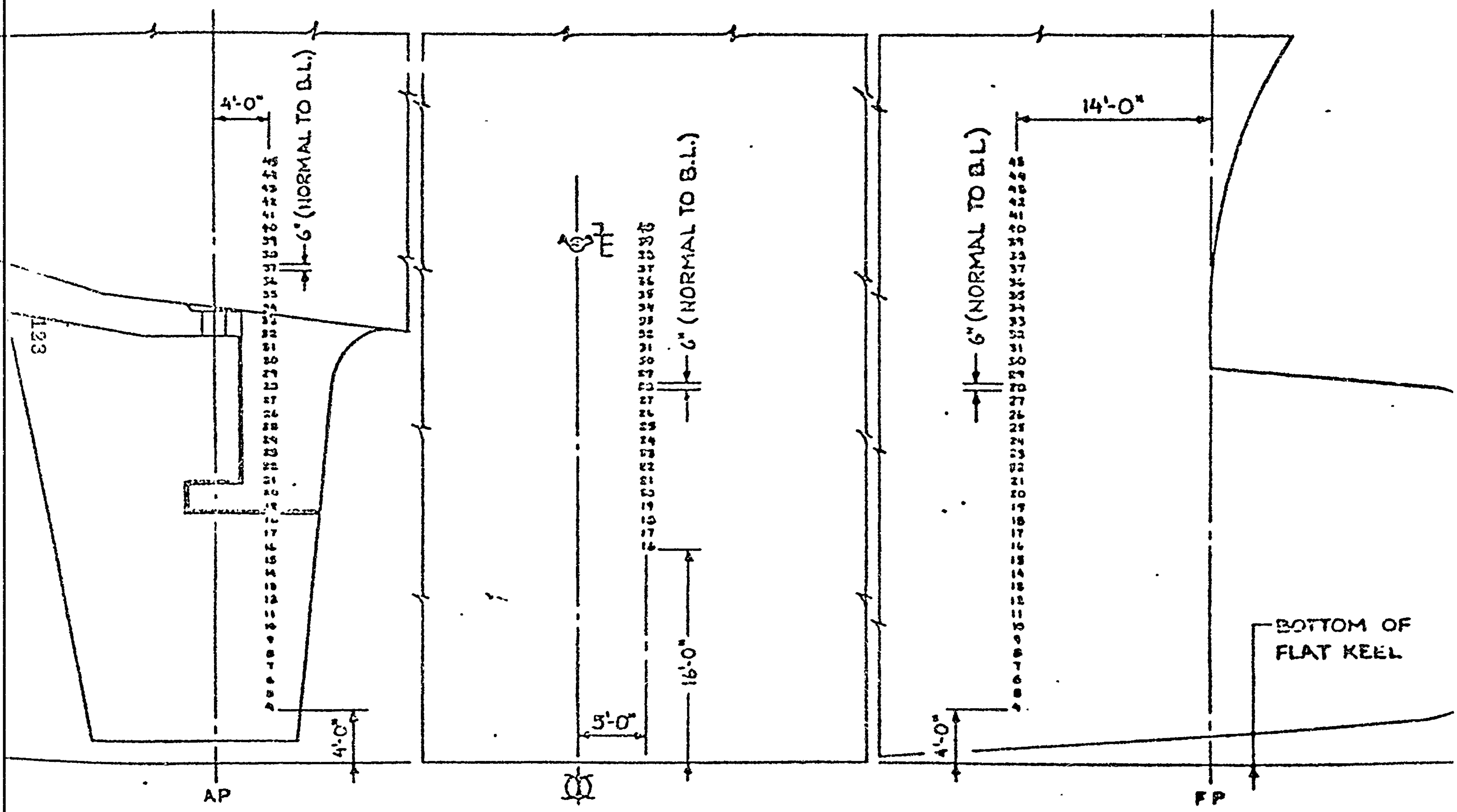
      (1) Longitudinal Extent – 16.41 ft.
      (2) Transverse Extent – 16.41 ft.
      (3) Vertical Extent – 6.56 ft.

   d) Local Damage – 29.9 inches in depth, normal to the hull.

Side penetration is assumed to occur anywhere along the length of the hull. Bottom penetration is assumed to occur anywhere within the limits specified. Local damage can occur anywhere on the hull.

FIGURE 23

DRAFT MARK LOCATIONS



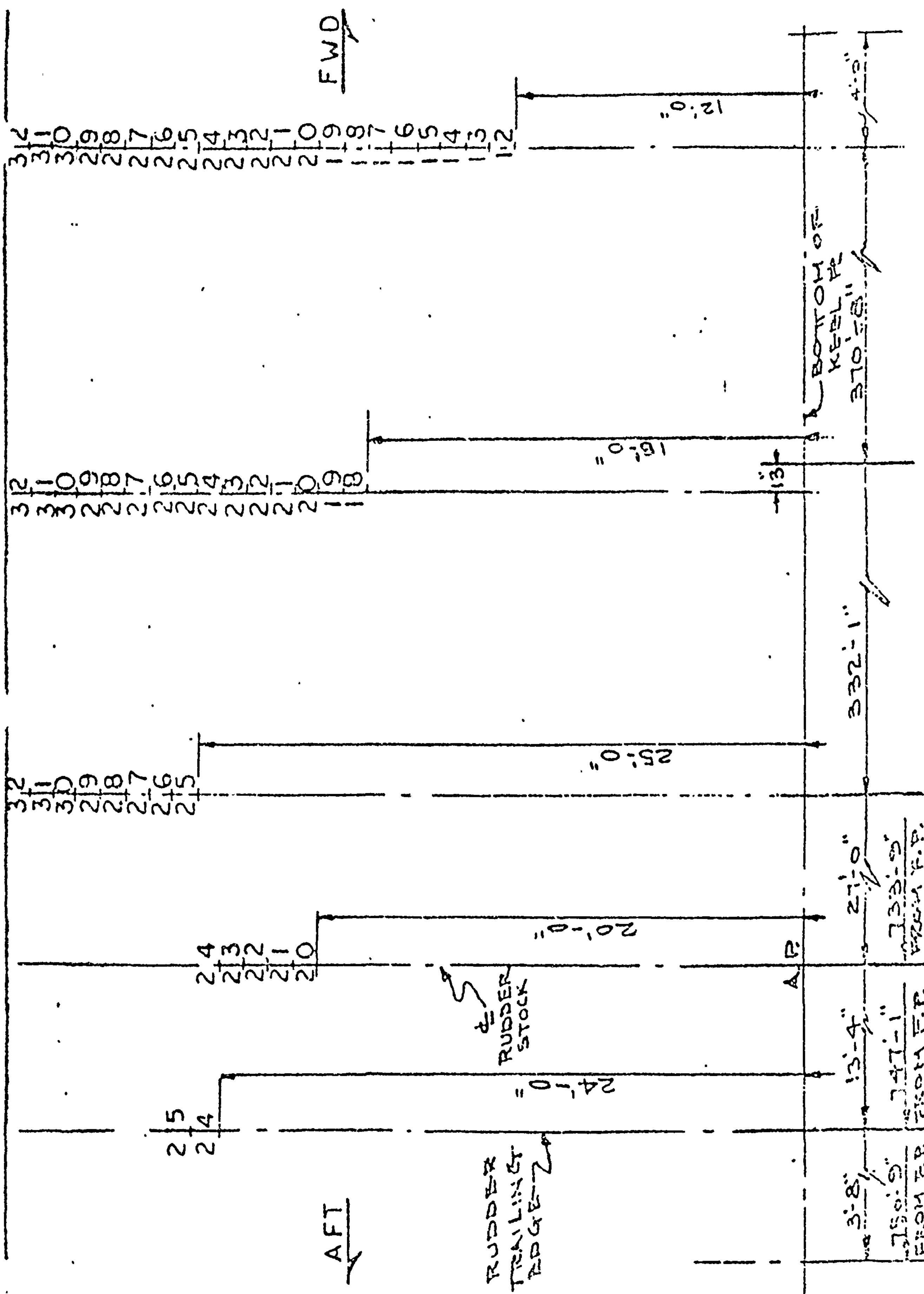

FWD
AFT
12'-0"
18'-0"
25'-0"
20'-0"
24'-0"
332'-1"
BOTTOM OF KEEL PL.
RUDDER STOCK
RUDDER TRAILING EDGE
FR. 2
A.P.

FIGURE 24

of the vessel's length at (near) the baseline over the length between perpendiculars. A scale of navigational drafts could be added to the draft diagram at the proper longitudinal location, allowing a direct reading of maximum draft, given forward and after drafts, or displacement and trim.

4.1.13 Calculation Forms

The actual calculations required for the determination of trim and stability are done by the ship's officer using various worksheets and calculation forms. Ninety percent of the participants in the workshop held at MITAGS considered the layout of these forms to be very important in accurately carrying out the required calculations.

In general worksheets are used to enter the weights and calculate moments due to the loads. They are usually blocked out into separate tables for various load categories (e.g. cargo, fuel, ballast, fresh water, and miscellaneous). The summary sheets provide tables to enter load sums, appropriate lightship values, and data from the hydrostatics table and other booklet sources. Table 33 is an example of a clear, standardized layout.

Instructions are usually not included on the forms themselves. The calculation forms and the worksheet information sometimes are incorporated in one ummary form, for vessels with sufficiently few compartments (Table 34). In some cases, the trim calculation form is separate from the stability form (Tables 35a and 35b). The booklet furnished for one class of tanker combined trim and strength calculations in one form. Table 36 comprises load worksheets, trim, strength, GM, and statical stability curve calculation forms.

TABLE 33

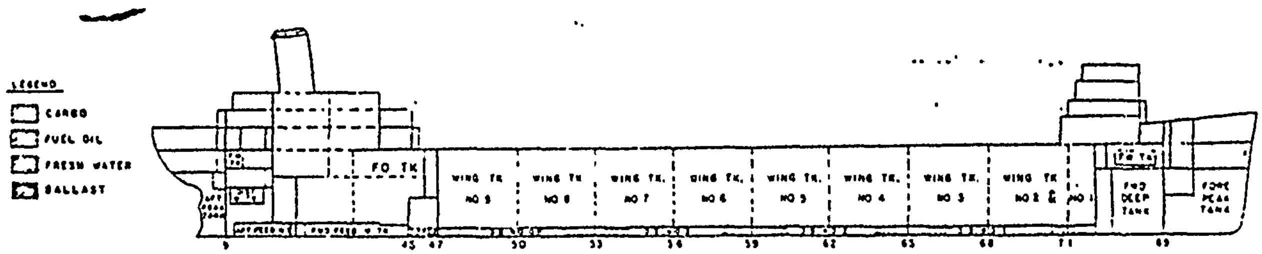
SUMMARY – WTS & CENTERS							CONDITION
ITEM	LOAD (TONS)	VCG	VERT MOM	LCG A+Ø-F	L MOM AFT	L MOM FWD	FREE SURFACE
LIGHT SHIP	29705	48.35	1436235	37.25	1106429		—
CREW & EFFECTS		113.86		338.25			—
STORES		76.03		–5.11			—
FULL LOAD ROLL STABILIZER		27.07		63.75			
FUEL OIL							
FRESH WATER AND SEWERAGE							
SALT WATER BALLAST							
LNG CARGO		68.63					—
MISCELLANEOUS TANKS							
NITROGEN STORAGE		87.92		76.17			
SWIM. POOL		105.20		334.60			
TOTALS	△	KG		LCG			FREE SURF

TRIM & DRAFTS	
DRAFT AT LCF	
MOMENT TO TRIM ONE INCH (MTI)	
LONG'L CENTER OF BUOYANCY (LCB)	
LONG'L CENTER OF GRAVITY (LCG)	
LONG'L CENTER OF FLOATATION (LCF)	
TRIMMING LEVER (LCG–LCB)	
TRIM BY (△ X LEVER/MTI) (+ BY STERN, – BY BOW)	
DRAFT AT FWD PERPENDICULAR (FP) (DRAFT AT LCF – (LCF/LBP + 0.5) X TRIM)	
DRAFT AT FWD MARKS (DRAFT (FP) + 0.008 X TRIM)	
MEAN DRAFT	
DRAFT AT AFT MARKS (DRAFT (AP) – 0.006 X TRIM)	
DRAFT AT AFT PERPENDICULAR (AP) (DRAFT (FP) + TRIM)	

STABILITY	
CENTER OF GRAVITY ABOVE B. L. (KG)	
CORRECTION FOR FREE SURFACE (TOT FR SURF ÷ △) FS	
CORRECTED CENTER OF GRAVITY (KG + FS) KG	
MAXIMUM ALLOWABLE KG (CURVE NO.)	
CORRECTED GM	

TABLE 34

	CONDITION.	DEPARTURE	



CARGO							
TANK	% FULL	TONS	KG	MOM	L.C.G FROM AP	MOM	F/S
SUB TOTAL							

BALLAST						
TANK	TONS	KG	MOM	L.C.G FROM AP	MOM.	F/S
FWD DEEP T/S		15.4[illegible]		[illegible]		
FORE PEAK TK		19.39		473.90		
[illegible]						
NO 5 WING TK						
NO 7 WING TK						
NO 8 WING TK						
SUB TOTAL						
FUEL OIL						
FO TANK P/S		24.30		100.50		540
[illegible] P/S		[illegible]		[illegible]		[illegible]
SUB TOTAL						1272
FRESH WATER						
[illegible] P/S		40		[illegible]		[illegible]
[illegible] P/S		[illegible]		[illegible]		[illegible]
[illegible] P/S		[illegible]		[illegible]		[illegible]
DIST W TK P/S		[illegible]		[illegible]		.0
SUB TOTAL						953

SUMMARY						
ITEM	TONS	KG	MOM	L.C.G FROM AP	MOM.	F/S
LIGHTSHIP CREW & STORES						
FUEL OIL						
BALLAST						
FRESH WATER						
HOLD CARGO						
DECK CARGO						
TOTAL						

MEAN S.W. DRAFT ________ FT
KM ________ FT
KG ________ FT
GM ________ FT
CORR. F.S. ________ FT
GM AVAIL ________ FT
GM REQ. (SEE PAGE) ________ FT
LCF (FROM AP) ________ FT
LCG (FROM AP) ________ FT
LCB (FROM AP) ________ FT
TRIM LVR FWD AFT ________ FT
MT1" ________ FT-TON
TRIM ____ FWD AFT ________ FT
DRAFT ____ FP ________ FT
DRAFT ____ AP ________ FT
% TRIM APPLIED AFT = ________ %

TABLE 35a

ITEM	WEIGHT (LONG TONS)	VCG (FEET)	V. MOMENT (FOOT TONS)	SOURCE
1. Effective Light Ship	7003.	31.16	218,229	Principal Characteristics
2. Bulk Cargo				Page 11, Line 100
3. Fuel Oil				Page 12, Line 200
4. Feed Water				Page 12, Line 300
5. Ballast				Page 12, Line 400
6. Calculated Departure Condition		*		
7. Mean Draft @ Line 6 Displacement ____________ **				
8. Actual Vessel Draft prior to Departure: Draft Fwd________ Draft Aft________ Mean Draft________				** From Actual Reading
9. Actual Departure Condition @ Line 8 Mean Draft			***	Displ. From Tables VCG Line 6
10. KM @ Line 9 Displacement				From Tables, Page 6
11. Repeat VCG Line 9				From Line 9
12. Uncorrected GM				Line 10 Minus Line 11
13. Total Free Surface Correction ________ Divided by Line 9 Displacement ________				
14. Corrected GM				Line 12 Minus Line 13

Calculations for Burned-Out Conditions:
This reflects consumption of all feed water and fuel oil well over normal requirements.
It is more severe than normal arrival condition and is obtained for guidance only.

ITEM	WEIGHT (LONG TONS)	VCG (FEET)	V. MOMENT (FOOT TONS)	SOURCE
15. Feed Water Consumed				
16. Fuel Oil Consumed				Recommended 400 L.T.
17. Total Liquids Consumed				Totals Line 15 & 16
18. Repeat Line 9				
19. Repeat Line 17				
20. Burned Out Condition		*		For Wt. & V.M. Line 18 Minus Line 19
21. KM @ Line 20 Displacement				Form Tables, Page 6
22. Repeat VCG from Line 20				
23. Uncorrected GM				Line 21 Minus Line 22
24. Total Free Surface Correction ________ Divided by Line 20 ________ Equals Free Surface Correction to GM				
25. Corrected GM				Line 23 Minus Line 24
26. Recommended Minimum GM				GM Curve, Page 9

* Obtain VCG by dividing Total Wt. into Total V. Moment.
** If Line 7 Draft and Line 8 Draft do not agree substantially, recheck all weights and moments.
*** Obtain V. Moment by multiplying weight by VCG.

Footnote for Page 12:

1. Weight and vertical moment on Board:
   Obtain On-Board weights by sounding each tank at departure. Multiply actual On-Board weights by VCG's listed above to obtain On-Board Vertical Moments.
2. Free Surface to Apply:
   Enter either the slack value or zero for each tank; do not skip any lines. Apply slack correction for largest single tanks, or combination of tanks, expected to be slack at any one time during the voyage.
   A fuel oil tank is considered slack unless it is stripped empty or filled more than 98%.
   A water tank is considered slack unless it is stripped empty or pressed tight into the vents. Compare the actual On-Board weights with the 98% and 100% weights listed above to decide whether or not a tank is slack.

Revised 6-7-72
Revised 2-25-72

TABLE 35b

ITEM	WEIGHT L. TONS	L.C.G. AFT F.P.	L. MOMENT FT. TONS	SOURCE
1. Effective Light Ship	[illegible]	[illegible]	[illegible],308,606	Principal Characteristics
2. Bulk Cargo				Page 11, Line 100
3. Fuel Oil				Page 12, Line 200
4. Feed Water				Page 12, Line 300
5. Ballast				Page 12, Line 400
6. Calculated Conditions		*		
7. Mean Draft @ Line 6 Displacement				From Tables of Form Page 6
8. LCG of Ship		Aft F.P.		From Line 6
9. LCB of Ship @ Line 6 Displacement		Aft F.P.		From Tables of Form Page 6
10. Trim Lever		Fwd/Aft		Distance between LCG Line 8 and LCB Line 9
11. Trimming Moment Multiply Displacement @ Line 6 ________ by Trim Lever @ Line 10 ________ Equals Trimming Moment		Fwd/Aft		
12. Trim Divide MT 1" ________ into Trimming Moment ________ Equals Trim (Inches)		Fwd/Aft		From Tables of Form Page 6 Line 11
13. Calculated Approx. Fwd & Aft Drafts **				

Draft Fwd = Mean Draft @ Line 7 ± ½ (Trim @ Line 12) = ________

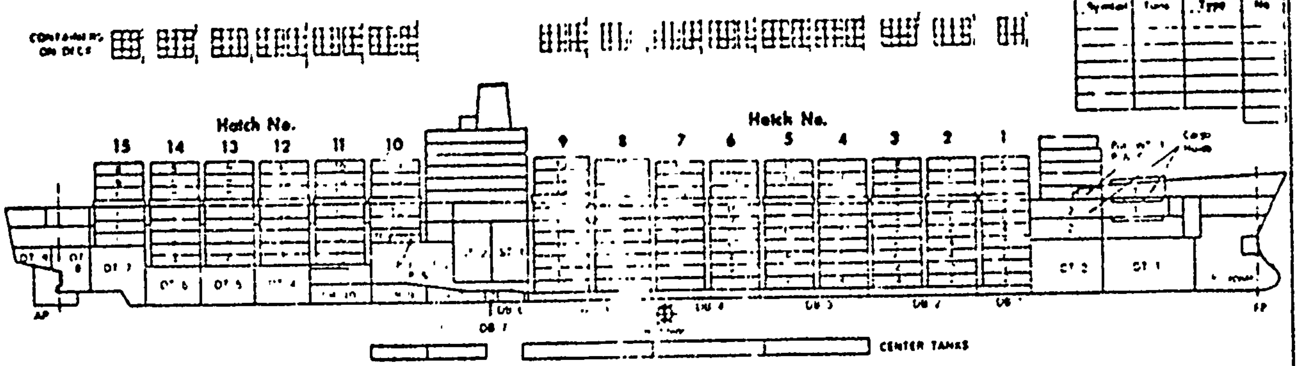
Draft Aft = Mean Draft @ Line 7 ± ½ (Trim @ Line 12) = ________

* Obtain LCG by dividing Total Weight into Total L. Moment.

** This is a practical approximation.

Revised 2-23-93

TABLE 36



LEGEND

Symbol	Liquid Tons	Type	No

Weights in long tons
Moments in ft tons
LCG from Midships
VCG above Base Line in Feet

CONTAINERS (Unit Weight Includes Stacking Frames 0.94 Tons Each)

Hatch No	No. Containers Max	Actual	Tons Unit	Total	Vertical C.G.	Moment	Aft C.G.	Moment	Forward C.G.	Moment
Containers in Holds										
1	26								254.73	
2	35								214.74	
3	44								174.73	
4	48								134.72	
5	58								94.72	
6	64								54.73	
7	68								14.74	
8	70						27.77			
9	70						72.77			
10	30						194.19			
11	50						234.16			
12	46						275.22			
13	38						315.22			
14	34						355.21			
15	18						395.24			
Total	694									
Containers on Deck										
1	18								254.73	
2	24								214.74	
3	24								174.71	
4	30								134.72	
5	30								94.72	
6	30								54.73	
7	30								14.74	
8	33						27.77			
9	30						72.77			
10	30						193.19			
11	30						234.16			
12	30						275.22			
13	24						315.22			
14	24						355.21			
15	18						395.24			
Total	402									
Grand Total	1096									
Cargo Holds										
Hold No. 1 Main Dk					70.48				348.08	
Hold No. 1 2nd Dk					59.91				344.42	
Hold No. 1 Stringer					45.23				251.56	
Hold No. 2 2nd Dk					54.43				296.04	
Hold No. 2 1st Stringer					14.93				292.32	
Total										

LIQUIDS	Tons Max	Actual	Vertical C.G.	Moment	Aft C.G.	Moment	Forward C.G.	Moment	Max. F.S.
Ballast Water									
F P	605		21.46				415.62		
O T 2	1377		20.58				47.37		
O B 1	341		3.38				257.28		
O B 2	408		3.33				[illegible]		
O B 3 P&S	218		3.45				[illegible]		
O B 4 P&S	505		3.50						
O B 8 P&S	410		5.57		153.06				
O B 9 P&S	464		8.41		197.35				
O T 3 P&S	815		16.69		272.81				
O T 4 P&S	1124		14.58		[illegible]				
O T 5 P&S	918		[illegible]		[illegible]				
O T 6 P&S	730		15.62		[illegible]				
O T 7P	587		[illegible]		[illegible]				
O T 7S	607		31.11		[illegible]				
O T 8	276		31.10		[illegible]				
O T 9	368		38.41		[illegible]				
Total	9,552								
Fresh Water									
D B 6P	110		[illegible]		[illegible]				
D B 6S	110		[illegible]		[illegible]				
Potable W T 1	[illegible]		[illegible]						
Potable W T 2 P&S	[illegible]		[illegible]						
[illegible] W T 1 P&S	[illegible]								
[illegible] W T 2 P&S	[illegible]		[illegible]						
[illegible]	[illegible]								

Fuel Oil	Tons Max	Actual	Vertical C.G.	Moment	Aft C.G.	Moment	Forward C.G.	Moment	Max. F.S.
O T 1	961		17.96				355.92		
O B 3 Center	433		3.08				112.75		
O B 4 Center	434		3.08				32.75		
O B 5 Center	473		3.08		57.71				
O B 8 Center	289		4.97		155.78				
O B 9 Center	431		6.83		152.30				
O B 10 Center	540		7.50		234.33				
O T 3 P&S	808		11.78		232.87				
S T 1 P&S	435		26.15		109.69				
S T 2 P&S	514		36.46		137.14				
Total	5,394								

SUMMARY

Symbol		Tons	Vertical C.G.	Moment	Aft C.G.	Moment	Forward C.G.	Moment	Max. F.S.
	Containers								
	Cargo Holds								
	Fuel Oil								
	Ballast Water								
	Diesel Oil & Fuel Add		19.52		242.21				88
	Fresh Water								195
	Mud in Light ship								
Deadweight Sub Total						(1)		(2)	
Deadweight Moment Total									
Operating Light Ship W/Mud		24,671	38.37	946,704	73.01	1,801,226			1,598
Displacement									

TRIM

L C F	ft	Draft at L C F		ft
L C B	ft	Trim at F P		ft
L C G	ft	Trim at A P		ft
Trimming Lever	ft	DRAFTS	F P	ft
Moment to Trim 1"	ft		A P	ft
Trim between Perpendiculars	ft		Mean	ft

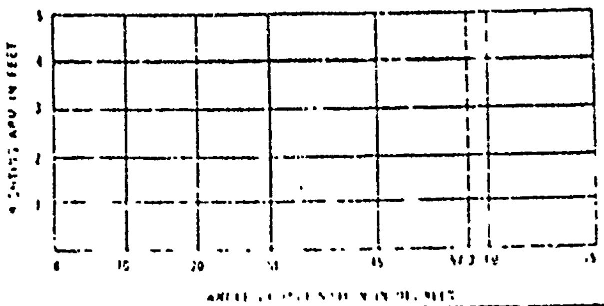
STRESS NUMERAL

(1)	Total Aft Deadweight Moment, ft tons (from Summary Above)	
(2)	Total Forward Deadweight Moment (from Summary Above)	
(3)	Total Forward and Aft Deadweight Moment (1) + (2)	
(4)	Max. Deadweight Moment (one half of line (3))	
(5)	Max. Moment at Light Ship Constant	2,357,827
(6)	Max. Moment at Displacement (4) + (5)	
(7)	Stress Numeral from page 5	

STABILITY

Metacenter above B L = KM	ft	Free Surface Moment		ft tons
V C G = KG	ft	Allowance for Free Surface		ft
Metacentric Height = GM	ft	GM corrected		ft
		GM required		ft

Angle of Inclination = θ	10	20	30	45	60	75
sin θ	0.174	0.342	0.500	0.707	0.865	0.966
Uncorrected Righting Arm (Tables) = Y						
KG (from V C G above)						
Free Surface allowance						
Virtual KG						
KG sin θ						
Corrected Righting Arm = Y KG sin θ						



In addition to these so-called "long forms", "short form" stability summary calculation sheets are often provided on vessels (primarily container, barge carrying, and RO/RO) for which the Z nomograph method is used. This method requires load items to be aggregated by horizontal "zone" on the load "worksheets". Examples of "short forms" stability calculation sheets follow. Table 37 includes instructions along with the zone weight sum tables and calculation tables. Table 38 includes the bar nomograph of required GM and "basic ship" GM. A rather poor presentation of this information is found in Table 39. Visual clarity of presentation is much better in form (Table 40) by virtue of the separation of the boxes. Example (Table 41) is only a summary form for the Z nomograph calculations. Determination of zone heights is done on other worksheets.

It has been found that individual mates generally use their own forms for trim, stability, and strength calculations. The vessel's booklet is of secondary importance to them. The reasons for this may be that the mariners and ship owner/operators (a) are the individuals most intimately familiar with the operational requirements of their vessels, and understand best what formats and calculation methods present difficulties for masters and mates or meet with the most resistance, and (b) are the parties most concerned with the economical operation of vessels, which in turn requires accuracy and speed in the determination of drafts, trim, and the adequacy of the loading from the standpoints of stability and strength.

The change observed in many "own forms" is the organization of calculation sheets by task. Since the order, importance, and length of calculations varies with the type of vessel and type of service, the organization of the calculation forms might also be expected

TABLE 37

SHORT FORM CALCULATION

Zone 1	(1) Weight	Zone 4	Weight
DB. Tank 1 C L		Container Level 3	
2 P/S		Cargo Oil Tank No 3	
3 C L		Deep Tank 2 P/S	
3 P/S		3 P/S	
4 Inbd P/S		4 P/S	
4 Outbd P/S		5 P/S	
5 Inbd P/S		7 P/S	
5 Outbd P/S		8 P/S	
5A Inbd P/S		15 P/S	
5A Outbd P/S		Aft Peak Tank	
5B Inbd P/S		[illegible] (20' Flat)	
5B Outbd P/S		Total Zone 4	
5C Inbd P/S		Zone 5	
5C Outbd P/S		Container Level 4	
6 Inbd P/S		Deep Tank 1 P/S	
6 Outbd P/S		16 (Upp) P/S	
7 Inbd P/S		Potable Water Tank P/S	
7 Outbd P/S		Unitized Cargo (3rd Deck)	
8 C L		Cargo Oil Tank No .	
8 P/S		Anti-Roll Tank (Upper)	
9 P/S		Total Zone 5	
Anti-Roll Dump Tanks P/S		Zone 6	
Total Zone 1		Container Level 5&5A	
		Distilled Water Tank P/S	
Zone 2		Total Zone 6	
Container Level		Zone 7	
Deep Tank 10 P/S		Container Level 6&6A	
10A P/S		Unitized Cargo (2nd Deck)	
10B P/S		Total Zone 7	
10C P/S		Zone 8	
10D P/S		Container Level 7	
11 P/S		Total Zone 8	
12 P/S		Zone 9	
13 P/S		Container Level 8	
17		Total Zone 9	
Total Zone 2		Zone 10	
Zone 3		Container Level 9	
Container Level .		Total Zone 10	
Anti-Roll Tank (Lower)		Zone 11	
Cargo Oil Tank No 2		Container Level 10	
Fore Peak Tank		Total Zone 11	
Deep Tank 9 P/S			
9 P/S			
14 P/S			
16 (Low) P/S			
Total Zone 3			

Zone	(2) Total L Tons	(3) Stab Factor
1		+
2		+
3		+
4		+
5		•
6		•
7		•
8		•
9		•
10		•
11		•
DWT		N.S.F.

SUMMARY	
(3) DWT	
Base Ship Weight	
(4) Total Displacement	
(6) N S F (Net Stab Factor)	
(7) GM Base Ship	+
(8) Free Surface Correction A	−
(9) GM Available	
(10) Mean Draft	
(11) GM Required	
(12) Margin (must be positive)	
If negative see step 12	

STEP NO.

① For any loading condition enter the tank and container weights (long tons) in each zone as indicated at left, and sum weights in each zone

② Transfer the sums to the column labeled "Total L. Tons" above, and sum the column to obtain the "DWT".

③ Transfer the "DWT" to the "SUMMARY" box.

④ Add the "DWT" and the "Base Ship Weight" to obtain the "Total Displacement".

⑤ With the Total Displacement and Zone Weight enter pages 111 through 121 to obtain the stability factors for each of the 11 zones. Enter the Stability Factors above and sum the column to obtain the Net Stability Factor, labeled as "N S F".

⑥ Transfer the Net Stability Factor, "N.S.F." to the Summary Box

⑦ With the Total Displacement enter page 122 to obtain the "GM for Base Ship"

⑧ See Note A page 122 to obtain the Free Surface Correction for anti-roll tanks in use.

⑨ Sum the Net Stability Factor, GM Base Ship and Free Surface Correction to obtain the GM Available.

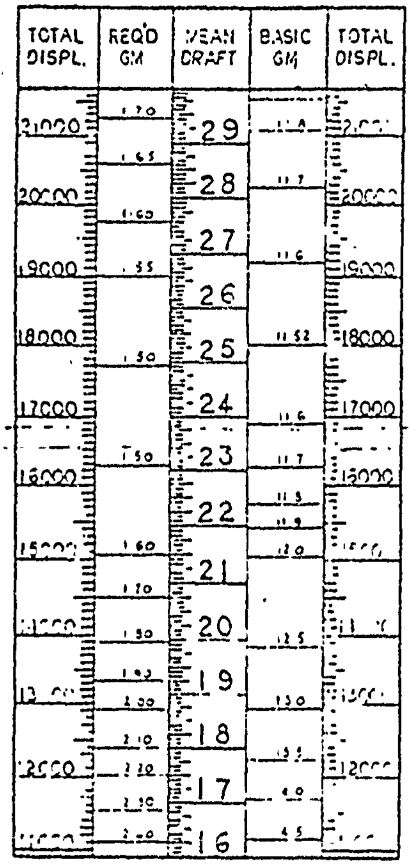
⑩ With the Total Displacement enter page 122 to obtain the Mean Draft

⑪ With the Mean Draft enter page 22 to obtain the "GM Required"

⑫ Subtract the GM Required from the GM Available to obtain the "Margin". The Margin must be positive. If the Margin is negative, see Item III(C) PG +

TABLE 38

RESULTANT "SHORT FORM" CALCULATION SHEET



CONDITION: BALLAST ARRIVAL

CORRESPONDING TO LONG FORM CALCULATION PAGE 36

DECK CARGO	TONS
TIER 4	
TIER 3	
TIER 2	
TIER 1	
TOTAL	

HOLD CARGO	TONS
TIER 3	
TIER 2	
TIER 1	
TOTAL	

ZONE 1	TONS
D.B. 1104 AFT	
F.O. FEED W. TANK P&S	15
AFT FEED W. TANK P&S	
TOTAL	15

ZONE 2	
FWD DEEP TANK P&S	
FORE PEAK TANK	
TOTAL	

ZONE 4	TONS
WING TANK NO 1-2 P&S	
WING TANK NO 3 P&S	1094
WING TANK NO 4 P&S	1102
WING TANK NO 5 P&S	1116
WING TANK NO 7 P&S	1137
WING TANK NO 8 P&S	1103
WING TANK NO P&S	
F.O. TANK P&S	90
D.O. STORAGE TANK S	
DIST. WATER TANK P&S	4
AFT PEAK TANK	
TOTAL	5638

ZONE 3	TONS
WING TANK NO 6 P&S	
WING TANK NO 9 P&S	
TOTAL	

ZONE 5	
FWD F.W. TANK P&S	2
AFT F.W. TANK	2
TOTAL	4

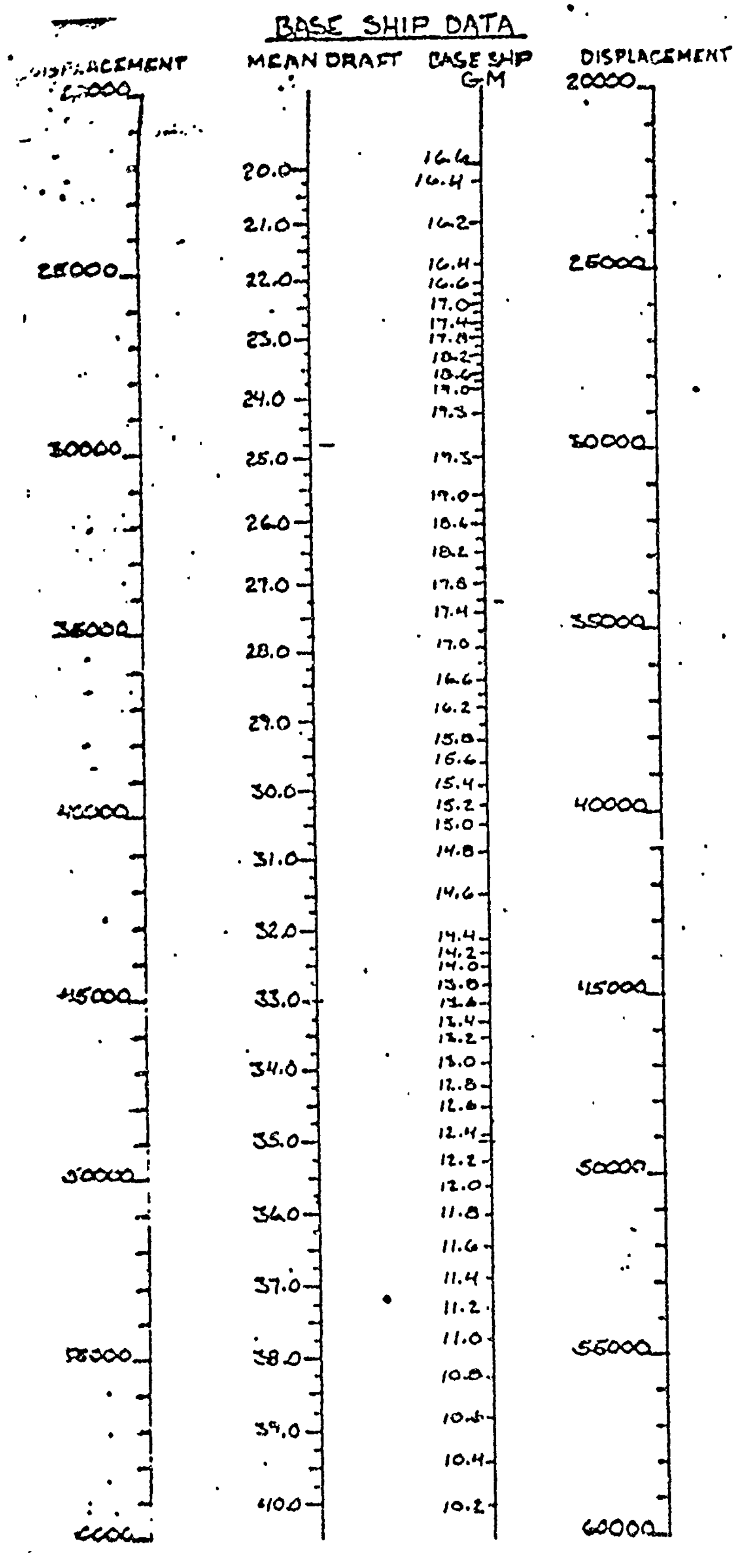
1. DEADWEIGHT			
ITEM	WEIGHT	STAB. FACTOR	TY FACTOR
ON DECK			
TIER 4			
TIER 3			
TIER 2			
TIER 1			
IN HOLD			
TIER 3			
TIER 2			
TIER 1			
IN TANKS			
ZONE 1	15		+0.001
ZONE 2			
ZONE 3			
ZONE 4	5638	-2.65	
ZONE 5	4	-0.005	
TOTAL	5637	-2.655	+0.001
			-2.555
NET STABILITY FACTOR			-2.554

2. DISPLACEMENT	TONS
OPERATIONAL LIGHTSHIP	[illegible]
DEADWEIGHT	[illegible]
TOTAL	16294

3 MEAN DRAFT	[illegible]

4 GM.	FT
BASIC GM	[illegible]
NET STABILITY FACTOR	[illegible]
AVAILABLE GM	[illegible]
REQUIRED GM	[illegible]

TABLE 39



ZONE	ITEM	WT. L.TONS	TOTAL ZONE WT	STAB. FACTOR +	STAB. FACTOR −
1	UPPER DK. CARGO				
2	MAIN DK. CARGO				
3	LOWER DK. CARGO				
4	DISTILLED WAT.				
	#10 P&S				
	#11 P&S				
	#12 P&S				
	FOREPEAK				
5	#2 P&S				
	#3 P&S				
	#9 P&S				
6	#4 P&S				
	#5 P&S				
	#6 P&S				
	#7 P&S				
	#8 P&S				
	#9 ℄				
	SEWAGE P&S				
7	RES. FEED P&S				
	#1 P&S				
	#2 ℄				
	#8 ℄				
	#3 ℄				
	#4 ℄				
	#5 ℄				
	#6 ℄				
	F.O. OVERFLOW				
	SLUDGE				
	ROLL STAB.				
	POTABLE WAT.				
FREE SURFACE OF TANKAGE IN USE					
		DWT =		= NET STAB. FACTOR	

DISPLACEMENT

BASE SHIP	18910 TONS
DEADWEIGHT	
TOTAL DISPLACEMENT	

MEAN DRAFT	

GM

GM FOR BASE SHIP	
NET STABILITY FACTOR	
AVAILABLE GM	
REQUIRED GM	

TABLE 40

VOYAGE NO. ________ CONDITION ______________________________

ZONE 1

SPAR DECK CARGO	TONS
Loaded Trailers	
Empty Trailers	
Autos	
TOTAL ZONE 1	

*ZONE 2

MAIN DECK CARGO	TONS
Loaded Trailers	
Empty Trailers	
Loaded Containers	
Empty Containers	
Autos	
TOTAL ZONE 2	

*SEE SPECIAL NOTE BELOW

ZONE 3

SECOND DECK CARGO	TONS
Loaded Trailers	
Empty Trailers	
Autos	
TOTAL ZONE 3	

ZONE 4

THIRD DECK CARGO	TONS
Loaded Trailers	
Empty Trailers	
Autos	
TOTAL ZONE 4	

ZONE 5

TANK TOP CARGO	TONS
Loaded Trailers	
Empty Trailers	
Autos	
TOTAL ZONE 5	

Assumed Weights:

Trailers ____________ 50,000#

Autos ____________ 6,000#

40 Ft. Containers ______ 42,560#

20 Ft. Containers ______ 31,360#

*Special Note: When Zone 2 carries containers, use Nomograph 2A on Page 79 in place of Nomograph 2 on Page 78.

ZONE 6

DOUBLE BOTTOM TANKS		TONS
P/S	No. 1	
P/S Outboard	No. 2	
P/S Inboard	No. 2	
P/S Inboard	No. 2A	
P/S Outboard	No. 3	
P/S Inboard	No. 3	
P/S	No. 4	
TOTAL ZONE 6		

ZONE 7

MISCELLANEOUS TANKS		TONS
Deep Tank	No. 1A	
Deep Tanks	No. 1B P/S	
Deep Tank	No. 2	
Deep Tank Aft	P/S	
Forepeak Tank		
Aft Peak Tank	C.L.	
Aft Peak Tank	P/S	
F.O. Settler		
Potable Water Tank		
Distilled Water Tank		
Stern Tube Compartment		
TOTAL ZONE 7		

I DEADWEIGHT

ZONE	TONS	STABILITY FACTOR	
1		+	-
2		+	-
3		+	-
4		+	-
5		+	-
6		+	-
7		+	-
DEADWEIGHT			
NET STABILITY FACTOR			

II DISPLACEMENT

BASE SHIP	
DEADWEIGHT	
TOTAL DISPLACEMENT	

MEAN DRAFT III	

IV GM

GM FOR BASE SHIP	
NET STABILITY FACTOR	
AVAILABLE GM	
REQUIRED GM (See Pg. 16)	

TABLE 41

SHORT FORM STABILITY CALCULATIONS

FREE SURFACE DEDUCTION

TANK	FREE SURFACE (FEET^4)
FORWARD FLUME TANK	
AFT FLUME TANK	

FREE SURFACE DEDUCTION = $\frac{\text{TOTAL FT}^4}{\text{DISPLACEMENT}}$

= ________ = ________ FT

TABLE I — DEADWEIGHT

ZONE	WEIGHT-TONS	STABILITY	
1		+	
2		+	
3		+	
1		+	
5			−
6			−
7			−
8			−
TOTALS		+	−
NET STABILITY FACTOR			

TABLE II — DISPLACEMENT	
BASE SHIP	16467.44
DEADWEIGHT	
DISPLACEMENT	
TABLE III — LCF DRAFT	
TABLE IV — G.M.	
1. GM FOR BASESHIP	
2. NET STABILITY FACTOR	
3. GM (UNCORRECTED)	
4. FREE SURFACE CORRECTION	−
5. AVAILABLE GM	
6. REQUIRED GM	

to differ. Also, some aspects of the type of service may have changed (e.g. vessel/shore responsibility relationship) from the time of the original vessel (and trim and stability booklet) design. On some vessels all the information for the calculation of stability is included on one sheet (Tables 42a and 42b). The only input from the mate is the weights. Free surface corrections are given, together with an exerpt from the hydrostatics table, including light load range of KM, required GM, draft, and displacement. One "own form" for stability has a hand-copied presentation of the hydrostatics on the reverse of the sheet. The clarity and legibility are somewhat less than the booklet's original presentation.

Similarly, on vessels with a large number of cargo compartments and tanks, separate loading sheets for cargo, ballast, and miscellaneous tankages are not uncommon. In separating sheets by task, additional paperwork is traded off against improved clarity. When the various moment calculations are made on different sheets, the weights must be entered more than once. One criticism of the Z nomograph stability short form is that it necessitates two compilations of weight: one organized by load category (cargo, fuel oil, fresh water, etc.), the other by zone. It would be possible to put longitudinal information into Z nomograph structure but this would sacrifice logical clarity and operational ease of calculation.

If the vessel will subsequently use the Mandelli method to obtain the bending moment numeral, the arithmetic required for the determination of forward and aft drafts can be reused for the strength assessment. When trim, stability, (and, where possible, strength) calculations appear in the same sheet (or set of sheets), the weights need only be entered once. They can then be multiplied

Table 42a and 42b were originally on one 8 1/2" x 14" sheet.

TABLE 42a

_____ VOY. NO. _____ DATE _____ FROM _____ TO _____ , _____ DEP_

ITEM	100 TON WT.	VCG	MOMENTS	DRAFT	DISP.	K.M.	GM REQ.
Light Ship	16161.2	37.66	608631	20:00	25,000	53.00	5.60
Crew & Stores		63.00		20:10	26,000	52.38	4.70
1-2-3 F		88.67		21:04	27,000	51.70	4.45
1-2-3 E		74.50		22:00	28,000	51.10	4.00
1 D		57.17		22:06	29,000	50.60	3.70
1 C		43.00		23:03	30,000	50.16	3.35
2 D		56.83		23:10	31,000	49.70	3.15
2 C		42.67		24:06	32,000	49.30	2.90
2 B		28.50		25:02	33,000	48.98	2.75
3 D		57.00		25:08	34,000	48.70	2.60
3 C		42.83		26:03	35,000	48.40	2.50
3 B		28.67		26:11	36,000	48.18	2.45
3 A		14.50		27:06	37,000	47.90	2.40
4-5-6-7-8				28:00	38,000	47.70	2.40
9-10-11-13				28:06	39,000	47.52	2.35
14-15-16-17 F		87.17		29:00	40,000	47.38	2.30
4-5-6-7-8				29:08	41,000	47.19	2.30
9-10-11-13				30:02	42,000	47.02	2.30
14-15-16-17 E		73.00		30:08	43,000	46.90	2.30
4-5-6-7-8				31:03	44,000	46.79	2.35
9-10-11 D		55.00		31:10	45,000	46.65	2.35
4-5-6-7-8				32:04	46,000	46.60	2.40
9-10-11 C		40.83		32:11	47,000	46.50	2.40
4-5-6-7-8				33:05	48,000	46.40	2.40
9-10-11 B		26.67		34:00	49,000	46.30	2.45
4-5-6-7-8				34:06	50,000	46.23	2.50
9-10-11 A		12.50		34:11	51,000	46.15	2.50
14-15 D		55.33		35:06	52,000	46.05	2.50
14-15 C		41.50		36:00	53,000	45.99	2.55
14-15 B		27.00		36:06	54,000	45.95	2.60
13-16-17 D		55.67		36:11	55,000	45.92	2.65
13-16-17 C		41.50		37:06	56,000	45.88	2.75
12-18 F		84.15		38:00	57,000	45.84	2.80
12-18 E		71.83		38:1½	57,200	45.80	2.90

TOTAL WT. CARGO _____ MOMENTS _____

TABLE 42b

ITEM	CAPACITY	WT.	VCG	MOMENTS	F/SURFACE
Forepeak	516.48		22.83		337.0
NO 1 SW Bal.	1313.96		14.77		8475.0
2 D/B P&S	1385.40		3.55		25103.0
3 D/B P&S	992.66		3.56		17734.0
4 D/B P&S	1365.90		3.57		28090.0
2 Wings P/S	4048		33.58		56628 ft^4
3 Wings P/S	2835		33.07		38336 ft^4
4 Wings P/S	4232		33.42		58584 ft^4
7 SW Bal. P	1748.51		32.85		101.0
7 SW Bal. S	1308.77		35.38		112.0
A/PK. P&S	1542.34		39.95		13121.0
Dist. Wtr. P&S	550.40		47.46		523.0
Potble Wtr. P&S	302.78		27.03		270.0
Fwd. F.O. TK. C/L	1079.00		23.14		3145.0
F.O. Storage P&S	1987.88		20.79		2797.0
6 Wing F.O. P	1306.99		31.19		82.0
6 Wing F.O. S	1366.46		30.43		136.0
L.O. Storage P&S	28.44		51.87		86.0
L.O. Gravity S	14.01		52.62		1.0
L.O. Settling P	20.63		52.27		23.0
Main L.O. Sump	18.44		10.32		8.0
Die. Oil Tk. P&S	112.72		15.81		126.0
400 Gal Emerg Diesel Day Tk.	1.32		65.60		3.0
500 Gal. Sew. Tk.	1.94		15.78		7.0
Bilge Slop Tk.	136.48		4.09		136598.0 ft^4
Fwd. Flume	693.16		31.08		10831.0
aft. Flume	989.42		14.76		14415.0

Displacement ________ Moments ________ (*________)

Cargo Displacement ________ C/MOMENTS ________

Total Displacement T/MOMENTS

Mom. ÷ Disp. ________ -KG

KM-FROM TABLES ________

KM-KG ________

GM ________

F/S. Cor. ________

GM Available ________

GM Required ________

GM Dif. ________

* For Free Surface Correction Divide Figure * by total DISPLACEMENT

by longitudinal and vertical centers and "factors" in different columns to arrive at the various moment or factor sums.

For vessels with a large number of load-carrying compartments, the optimum set-up of the forms may be to separate the various tasks, in order to aggregate weights before performing moment calculations. This would minimize the number of multiplications required. An example of combining tasks on one calculation sheet is found in the "company forms" for a chemical carrier. Its "Trim and Stress Short Form" (Table 43) includes values of tankages for the full-weight condition and corresponding moments and "factor" products. In addition, small tankages are aggregated to an "average condition" weight and moments and factor products are overprinted in the appropriate position in the table.

A novel approach to strength calculations is found in a tanker "company form" which included a table of "changes in stress per 100 tons loaded" for particular tankages (Table 44). Since there is a small number of tanks in this ship which are usually full when the vessel is in the loaded condition, the strength assessment is reduced to calculation of the changes in stress due only to those tankages which differ from the "basic loading condition".

Several "company forms" are responses to the use of computers in the loading of the vessel. These are simple tables on which to enter weights and/or display important results where computer printout is unavailable or insufficient (Figure 25). Some of the loading forms exhibit a generalized format; for example, on a container/break bulk vessel, a loading form had blank bay and tier headings and separate tables for containers and break bulk (Figure 26).

TABLE 43

TRIM AND STRESS SHORT FORM

#	ITEM	Cap Full LT	WEIGHT LT/100 (a)	FACTOR (b)	HOG numeral (a x b) (c)	FACTOR (d)	SAG numeral (a x d) (e)	FACTOR (f)	LONG moment (a x f) (g)
1	Forepeak	306		4.82		0.65		+22350	
2	Deeptank PS	760		4.31		1.26		+19350	
3	Pot Amid	35		2.21		3.77		+ 5030	
4	Cofd fr 46-47H	70		3.50		2.80		-13310	
5	DB Fwd PS	156	3.30	4.20	14.60	2.27	6.74	-16800	- 57137
6	DB aft PS	72		4.86		1.68		-20850	
7	Dist in E/R PS	36		5.06		1.52		-22050	
8	FW St Gr Flat	28		5.19		1.40		-22900	
9	Afterpeak	54		5.30		1.30		-23850	
10	FO Wings PS	720		3.90		2.52		-15040	
11	CT #1 PS			3.92		1.73		+16740	
12	CT #2C Fwd			3.63		2.08		+14830	
13	CT #2 PS			3.54		2.17		+14240	
14	CT #2C Aft			3.38		2.36		+13140	
15	Dk Tk "A"			3.03		2.78		+10830	
16	CT #3 Across			2.97		2.87		+10390	
17	Dk Tk "B"			2.81		2.94		+ 9300	
18	CT #4 PS			2.43		3.51		+ 6740	
19	CT #4C			2.40		3.54		+ 6620	
20	CT #5C			1.91		4.11		+ 3440	
21	CT #5 PS			1.89		4.14		+ 3290	
22	CT #6C			1.48		4.65		- 360	
23	Bal #6 PS	1320		1.48		4.65		- 360	
24	CT #7 Across			2.08		4.14		- 4010	
25	CT #8C Fwd			2.56		3.70		- 6910	
26	Bal #8 PS	936		2.59		3.67		- 7140	
27	FW #8C Aft	157		2.78		3.51		- 8210	
28	CT #9 Fwd PS			3.03		3.28		- 9750	
29	CT #9C			3.19		3.16		-10790	
30	Bal #9 Aft PS	484		3.41		2.97		-12100	
31	Total DWT 1-30								
32	Lt Ship+Stores		66.00	----	90.42	----	33.13	- 3130	-206580
33	Displacement								
34	DWT Corr (-) (3xline 31-a)			3.00		3.00			
35	Result Numeral for Long Mom			=		=		=	

HOGGING & SAGGING NUMERALS SHALL NOT EXCEED 100

TOTAL DISPLACEMENT (line 33a) ________ LT
MEAN SW DRAFT (hydrostac prop) ________ Ft

L.C.G. to ⊠ = $\frac{\text{LONG MOM}}{\text{TOTAL DISPLC}}$ ________ Ft

L.C.B. to ⊠ (hydrostac prop) ________ Ft

TRIM LEVER = Long dist between L.C.G. & L.C.B. ________ Ft

MOM TRIM 1" (hydrostac prep) ________ Ft/T

TRIM = $\frac{\text{Tot Displc x Trim Lever}}{\text{Mom Trim 1"}}$ ________ In

TRIM FWD = TRIM x .50* = ________ In
TRIM AFT = TRIM x .50* = ________ In

DRAFT FWD = MEAN (-)**TRIM FWD ________ Ft
DRAFT AFT = MEAN (+)**TRIM AFT ________ Ft

* If addl accuracy req apply "Z" corr
** Reverse signs when L.C.B. is aft of L.C.G.

Note: col (a)
Line #3-9 figure = sum of avg cc [illegible] weights

	(a)	(c)	(e)	(g)
Forepeak	3.00	14.46	1.95	+[illegible]050
Deep Tk	7.60	32.76	9.58	+1[illegible]060
FO Wngs	7.20	28.08	18.14	-1[illegible]288
Bal 6PS	13.20	19.54	61.38	-[illegible]752
Bal 8PS	9.36	24.24	34.35	-[illegible]330
FW 8CA	1.57	4.36	5.51	-[illegible]890
Bal 9PS	4.84	16.50	14.37	-53564

Above table = full weight condition

Port ________________ Date ________

Voy # ______ Signed ________________

TABLE 44 TABLE FOR ESTIMATING STRESSES IN WEATHER DECK AMIDSHIPS FOR STANDARD HOGGING AND SAGGING CONDITIONS VARIATIONS @ LOAD DRAFT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				HOGGING		SAGGING	
ITEM	BASIC LOAD CONDITION L. TONS	DESIRED LOAD CONDITION L. TONS	CHANGE IN HUNDREDTHS OF TONS	CHANGE IN STRESS PER 100 T	TOTAL CHANGE IN STRESS	CHANGE IN STRESS PER 100 T	TOTAL CHANGE IN STRESS
Basic Load Condition					4000		19427
Light Ship	8997			0		0	
Crew & Stores	120			0		0	
Fuel Oil:							
Wings	677			+ 60		− 32	
Settlers	255			+ 63		− 36	
Deeps				+ 123		− 150	
Feed Water: Distilled	50			+ 163		− 115	
Potable Water: F.W.	25			+ 220		− 160	
Ballast Tks. & Coffs:							
Forepeak				+ 167		− 200	
Fwd. Coffs				+ 88		− 122	
Aft Coffs				+ 43		− 22	
Aft Peak				+ 201		− 146	
Cargo:							
Tanks No. 1	2574			+ 72		− 97	
2	3034			+ 27		− 50	
3	3155			− 20		− 2	
4	3170			− 68		+ 46	
5	3174			− 115		+ 95	
6	3174			− 162		+ 143	
7	3174			− 130		+ 119	
8	3152			− 80		+ 79	
9	3090			− 30		+ 39	
10	[illegible]			[illegible]		− 1	
TOTALS	[illegible]						

Note: With the above [illegible] for any load condition [illegible] be closely pro[illegible] Hogging & Sagging wave positions by following the steps described below.

1. List load distribution in Column (2).
2. Enter difference (in hundreds) from basic load in Column (3), retaining algebraic sign.
3. Multiply entries in Column (3) by figures in Columns (4) & (6), & enter results in Columns (5) & (7) respectively, observing rules for algebraic sign.
4. Add algebraic sum of entries in Columns (5) & (7) to stresses heading these Columns, thereby obtaining resultant stresses.

In no case should these resultant stresses exceed 21000 PSI, and the most favorable loading exists for the ship when Hogging & Sagging stresses are approximately equal.

FIGURE 25 TABULATION OF CONTAINER TIER WEIGHTS

CELLS #4 THRU #9 TOTAL CELL WEIGHTS OF ADJACENT CELLS MUST NOT DIFFER BY MORE THAN 300 TONS.

TIER	1	2	3	4	9	10	11	TOTAL
10								
9								
8								
7								
6								
5								
4								
3								
2								
TOTAL								
	[illegible]	400	800	1200	1000	700	300	10,280

FIGURE 26

SS ____________ VOY ______

CARGO SUMMARY SHEET PORT

																						TOTAL			TOTAL
		REF	GEN	40'	REF	GEN	40'	REF	GEN	40'	REF	GEN	40'	REF	GEN	40'	REF	GEN	40'	M/T 20'	M/T 40'	REF	GEN	40'	D/W
	CTRS																								
	D/W																								
	CTRS																								
	D/W																								
	CTRS																								
	D/W																								
	CTRS																								
	D/W																								
	CTRS																								
	D/W																								
TOTAL	CTRS																								
	D/W																								
TOTAL D/W																									

BREAK BULK CARGO	LIFTS	D/W	LIFTS	D/W	LIFTS	D/W	LIFTS	D/W	LIFTS	D/W	LIFTS	D/W		LIFTS	D/W	
TOTAL																

Many company forms arise from a desire to standardize fleet records, where T&S forms differ. One such form for bending moment calculation (Figure 27) includes footnotes identifying figures which differ from vessel to vessel within the calss (e.g. maximum cell weights, tank capacities).

Other individualized characteristics observed of some of the forms include: a hydrostatic properties table with differences between consecutive entries for ease of interpolation. This makes the table bulkier. It would be better for the intervals between entries to be small enough that interpolation is unnecessary. A note to this effect should be included; a single summary form with clearly marked spaces for stability in both departure and arrival conditions, enabling one to assess at a glance the most crucial point of the voyage with regard to stability; a space for calculated and observed drafts, for comparison when a reading can be taken; a space for the vessel name, date, and voyage origin and destination. In general, careful attention is paid to properly identifying calculation forms. The ship's profile on the load summary has a legend, composed of various cross hatchings and shading, with which to represent the different load items (cargo, fuel, ballast, etc.) in the various compartments. This exercise is not done by mariners in preparing the forms.

4.2 Technical Analysis of Methods of Calculation

The preceding review of specimen T&S booklets indicated that format and presentation of existing booklets are unstandardized and often not of uniform technical and graphical quality. This section will analyze the validity and relevance of the approaches and

Use this form for:
Vessel #1
Vessel #2
Vessel #3
Vessel #4

BALLAST

FIGURE 27

TANK	CAP. TONS	WEIGHT TONS	DISTANCE FROM ⊠	MOMENT FT-TONS
1 P/S DOUBLE BOTTOM	336		203.1	
2 CL DOUBLE BOTTOM	459		120.9	
2 P/S DOUBLE BOTTOM	294		115.4	
3 CL DOUBLE BOTTOM	473c,d 0e		22.0	
3 P/S DOUBLE BOTTOM	480		30.7	
4 CL DOUBLE BOTTOM	483		59.0	
4 P/S DOUBLE BOTTOM	446		56.1	
4 P/S DOUBLE BOTTOM	200		208.0	
M I P/S DOUBLE BOTTOM	216		145.9	
FOREPEAK	260c,d 264e		314.6	
AFT PEAK	252		310.6	
FLUME TANKS	438		102.2	
TOTAL	4383 c,d 3914 e			

c: LANCER LEGION
d: LIBERTY LARK LYNX ASTRONAUT
e: APOLLO AQUARIUS

SUMMARY OF CALCULATIONS
LONGITUDINAL BENDING MOMENT

SS ________________ VOY ________________

BY ________________ DATE ________________

	ITEMS	A LONG TONS	B MOMENT ft-ton
1	LIGHTSHIP WEIGHT		
2	LIGHTSHIP x L.B.P. x 0.183		
3	CARGO		
4	BALLAST TANKS		
5	CONSUMABLE TANKS		
6	TOTAL (Items 1-5)		
7	ITEM 6 B DIVIDED BY 2		
8	Δ/Δ_0 ITEM 6A DIVIDED BY 12,565		
9	a FROM GRAPH		
10	a = 210,186		
11	ITEM 7 B MINUS ITEM 10 B		
12	LOADING NUMERAL (ITEM 11B / 310,000) X 100		

CARGO

CELL	MAX. WEIGHT	WEIGHT TONS	DISTANCE FROM ⊠	MOMENT FT-TONS
1	700		237.0	
2	1360		191.5	
3	1160		146.5	
4	1800		101.7	
5	1980		56.5	
6	1940		11.5	
7	1980		33.3	
8	1950		78.5	
9	1360		207.3	
10	180		252.3	
11 below	. c 200 d e		257.5	
11 above	160 c 240 d 300 e		298.5	
TOTAL	16,240 c 16,520 d 16,580 e			

c: Vessel #1 d: Vessel #2 Vessel #3 e: Vessel #4

CONSUMABLES

FUEL OIL

TANK	CAP. BBLS	CONTENTS BBLS	TONS	DISTANCE FROM ⊠	MOMENT FT-TONS
DEEP TANK I	915c 1094d 1823e			206.7	
DEEP TANK II P/S	2419c 2886d 4783e			268.3	
WING TANK III P/S	3929			231.2	
WING TANK IV P/S	4599			185.9	
DEEP TANK V P/S	4953c 4688d,e			208.9	
DEEP TANK VI P/S	1500			255.5	
SETTLERS	4999c 5092d,e			111.7	
TOTAL	22926c 23786d 26413e				

FRESH WATER

TANK	CAP. TONS	WEIGHT TONS	DISTANCE FROM ⊠	MOMENT FT-TONS
M I - A	54		129.2	
M I - B	101		166.8	
POTABLE P/S	73		114.3	
DISTILLED	23		180.5	
TOTAL	251			

c: Vessel #1
d: Vessel #2 Vessel #3
e: Vessel #4

F.O. & F.W. TOTALS

WEIGHT ________ TONS
MOMENT ________ FT-TONS

assumptions underlying the booklet and the calculations involved.

4.2.1 GM, Draft, and Trim Calculations

The stability of a ship at a low angle of heel depends on the vessel's displacement, the height of the vessel's center of gravity, and the height of the vessel's metacenter. The displacement and the height of the ship's metacenter are tabulated in the hydrostatic properties, together with the ship's drafts (which can be visually chekced). A computational effort is necessary to determine the vessel's virtual center of gravity, which involves computing the weights, centers of gravity, and the free surface corrections of the cargo and the liquid tanks.

The procedure of all the T&S manuals in the long form is essentially identical. The procedures require that the operator:

1. Compute the weight, vertical moments, and longitudinal moment of lightship, crew, stores, tankage, and cargo.
2. Add up the weights and moments for these categories.
3. Divide the moments by the total weight to compute the vertical and longitudinal centers of gravity.
4. Add up the moments of inertia of slack tanks' free surface. The combined free surfaces of the slack tanks of each consumable type of liquid must equal or exceed the free surface effect of the largest port and starboard pair of such tanks.*

* This results in overestimation of the free surface correction, and gives a margin of safety which permits fuel tanks to be used in any order, provided that certain operational restrictions are observed.

5. Divide the total free surface moment by the total displacement volume to establish the free surface correction to virtual GM.
6. Enter the table, graph, or nomograph of hydrostatic properties with total displacement to find
   a. mean draft
   b. KM
   c. LCB
   d. LCF
   e. MTI
7. Compute GM from KM and KG.
8. Apply free surface correction to obtain virtual GM.
9. Compute trim from LCG, LCB, and MTI.
10. If GM is less than that required by the curve of required GM, use gain in GM from ballasting table to add/delete/rearrange cargo or tankage until GM is satisfactory.
11. Evaluate trim, using similar iterative process and criteria provided.
12. Proceed to the longitudinal strength calculations.

Computation of the weights and moments on most unitized cargo ships is performed by shore personnel usually aided by some type of computer, and the T&S booklets appear to suffer from neglect. The calculations are not arranged with sufficient attention to arithmetic simplicity. The operations do not follow the logic of the calculation, and the sequencing of operations - addition before multiplication, for example - is not always orderly. Aspiration to arithmetic simplicity is the basis of the many short forms - the Z nomograph, the variety of ships' own forms, and the company short forms. The degrees of

aggregation of weights with varying centers of gravity vary with the particular "short form". Those short forms which are most acceptable to users aggregate only cargo, and treat each location of tankage and consumables separately. To simplify calculations, particularly in barge carrier/container ship operation, cargo spaces are divided into vertical and horizontal zones. Total weight of cargo in the zone is then multiplied by the zone's common lever arm, saving arithmetic effort. All containers, etc., in the same tier or stack share the same vertical pallets, or longitudinal CG, so that better tabular layouts can be devised with no loss of accuracy. This same economy can be provided for longitudinal moments (trim and strength calculations) if the long form is similarly laid out.

Calculation of the free surface correction is based on the following facts: (1) the loss of GM (i.e. the virtual rise of G) is directly proportional to the moment of inertia of the free surface area about the fore and aft axis through its centroid; (2) the loss of GM is inversely proportional to the ship's displacement volume; and (3) the loss of GM is proportional to the ratio of the densities of the liquid presenting the free surface and the water in which the ship floats.

The application of free surface correction is based on the use of a maximum correction to permit safe use of pairs of consumables tanks in any order. When order of fuel burning is becoming more circumscribed, this conservative treatment may be unwarranted. The transient free surface moments which develop during liquid loading can be a serious consideration. The problem is most acute on small parcel tankers, where IMCO/Port of Rotterdam rules allow sidewalls or double hull construction

with no centerline bulkhead. These tankers have little freeboard (the volume is not needed to carry the cargo), which limits the range of stability. Since the loss of GM is inversely proportional to the square of the number of longitudinal compartments, the moments which can be developed (especially with cargo of specific gravity greater than 1.0) are very large in relation to the displacement of the vessel. Continuous knowledge of the free surface correction or explicit operating restrictions are necessary for safe loading and discharging operations.

The Z nomograph short form is used to calculate vessel stability. It was developed for the following reasons:

1. To provide a method for calculating stability which is flexible enough to permit its application to a wide range of vessel and cargo types.
2. To produce accurate results throughout the full range of vessel loading.
3. To present the data in a form which has physical meaning to the user.
4. To eliminate error-prone interpolation.
5. To reduce the arithmetic process to simple addition or subtraction.

This method is shorter because

1. A "basic ship" and free surface correction are assumed constant for all conditions of vessel loading. The "basic ship" includes:
   a. Lightship
   b. Crew and effects
   c. Passengers
   d. Nonconsumable stores

e. 2/3 consumable stores

f. Lube oil

g. Small diesel oil and other miscellaneous small service tanks

h. Fixed ballast

Free surface correction is calculated for a specified set of cargo, fuel, ballast, and miscellaneous tankages.

2. Compartments with approximately the same vertical center of gravity are aggregated into "zones", reducing significantly the number of effective multiplications required.

3. The multiplications required for the determination of vertical moments are done graphically, requiring only the use of a straight edge. Thus the arithmetic manipulations required for reduced to a small number of additions and subtractions: summations of zone (horizontal level) weights and summation of (positive and negative) "stability factors".

The accuracy of the Z nomograph method depends on:

1. The number of horizontal zones used. The more zones used, the closer the assumed vertical lever will be to the actual, while the number of calculations required increases. In general, assumptions of zone centers .5 to .6 of the height above the bottom of the zone lead to low estimates of available GM.

2. The variability of the items included in the "basic ship". A note is usually included in the general instructions indicating that the displacement by the short form may differ

from the long form for this reason. Usually this error is very small.

3. The difference between the assumed and actual free surface corrections. This usually leads to a "conservative" (low) estimate of available GM, because that tank or pair of tanks with the greatest free surface is assumed slack (for liquids not in the "pressed-up" condition).

The advantages of the Z nomograph method are somewhat offset by its lesser accuracy, the required reference to several nomographs on different pages of the booklet, and the requirement for a similar moment calculation in the longitudinal direction for the determination of trim.

The Z nomograph method is most useful for tedious calculations involving many weight items such as those for a container ship. This, however, is precisely where electronic calculators are most valuable (and most common) and where shoreside input is available. Typically, shoreside personnel can provide all necessary information on cargo weights and centers. Ship's personnel need only account for additional weights and centers of fuel and consumables, which are relatively few in number and hence not computationally burdensome.

4.2.2 Statical Stability Curve Calculations

The current American approach to stability emphasizes the ships' initial GM and pays little attention to the statical stability curve approach embodied in the IMCO rules for stability.

The basic reason for this is that the stability criterion used for American ships is a combination of wind heel and damaged stability criteria. Both of

these can be expressed partly in terms of initial GM, yet these criteria will almost always require at least 50% more GM than the IMCO rules require. As these are the criteria binding on U.S.-flag vessels, there is little point in the construction of a vessel's statical stability curve as the result will always be satisfactory.

On the other hand, these criteria, while more stringent, have very little to do with the normal operation of vessels. They are more concerned with the behavior of the vessel in dire emergency. In addition, they add little to an officer's understanding of what is happening to his vessel in a rough sea.

The statical stability curve approach, however, focuses on more frequently encountered perils - namely, capsizing through inadequate range of stability and damage to hatch covers and subsequent flooding of the hold below. When combined with recent Coast Guard work on syncronous rolling,[1] it yields additional insight into situations where even large vessels can roll to tremendous angles, though loaded properly according to existing Coast Guard requirements.

All of the above situations effect little if any change in the vessel's stowage or ballasting. Hence there is almost no operational reason to do these calculations routinely - in fact they are not usually done. However, a thorough understanding of the principle underlying the IMCO rules will improve a master's understanding of a vessel's behavior and perhaps improse his seamanship.

Some U.S.-flag T&S booklets nevertheless present the cross curves of stability and instructions to prepare

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[1] Quoted in Hendrickson (1979).

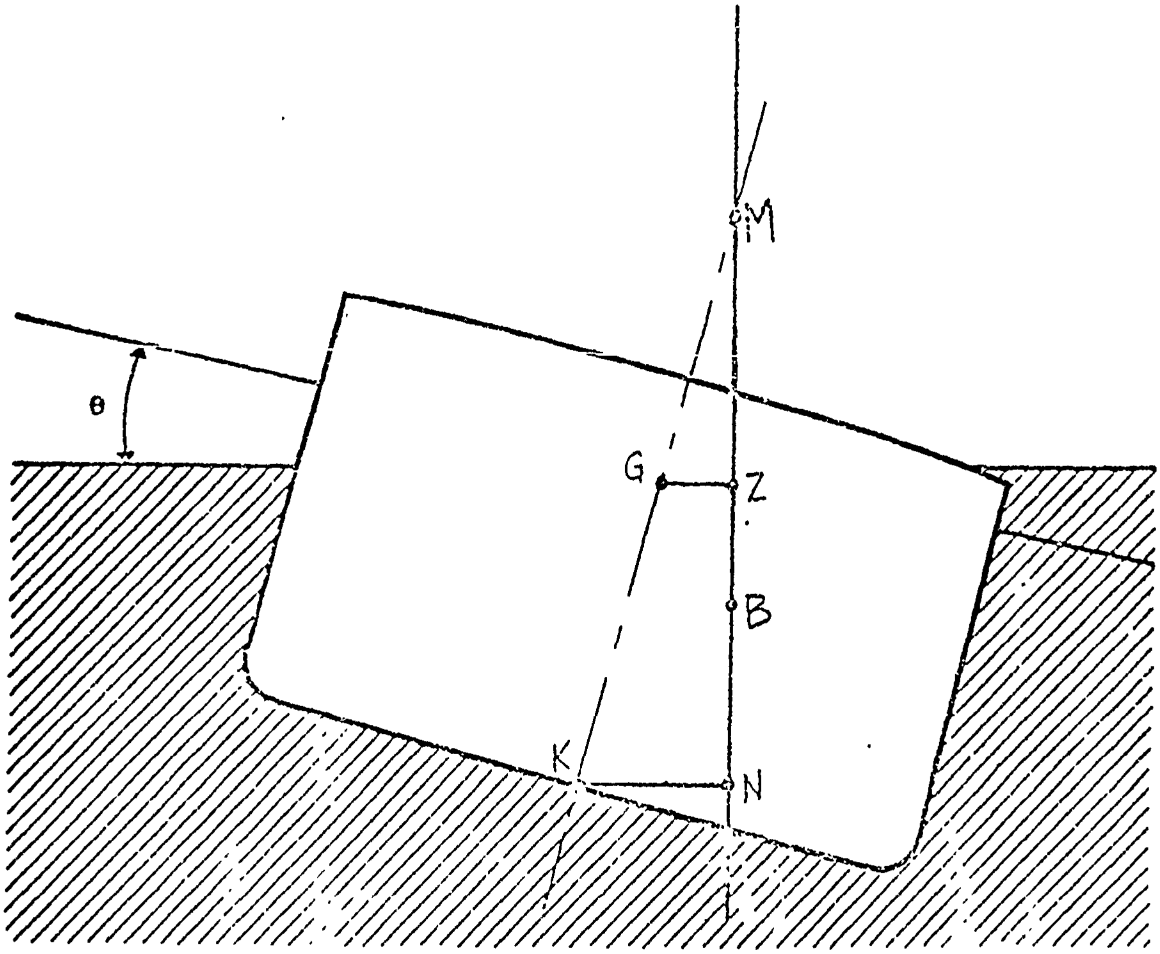
the statical stability curves. Usually this material is presented with an assumed KG of the vessel somewhere near its actual. (For example, cross curves diagram will state that all curves are for an assumed KG of 25 feet.) The user obtains the actual righting arms (GZ) for each cross curve by adding a correction equal to the product of the sine of the angle of heel and the algebraic result of subtracting the assumed KG from the actual KG. Thus, if the actual KG is above the assumed, the correction is negative and the true GZ is less than the value read directly from the graph; if the actual KG is below the assumed, the correction to the GZ value is positive. This presentation of cross curves information can lead to sign errors. A preferable approach is to present values of KN (see Figure 28) on the cross curves. To obtain the actual GZ values, the correction will always be subtractive and equal to KG x $\sin\theta$. This latter approach uses an assumed center of gravity at the baseline.

A further conceptual problem presents itself when these curves are used in earnest. For most uses it is *various areas under this curve*, not the curve itself, that matter. In all current approaches, it is necessary to lay out the curve and integrate the area under the curve to use the curve as intended. If this approach is to be further developed, a simple means to integrate the curve without use of a planimeter or numerical integration will be needed.

For this purpose, a graph analogous to the cross curves can be provided. The graph would present curves of

$$\int_0^{\theta} KN d\theta$$

as a function of vessel displacement for the desired angles of heel. To obtain the corrected righting energy



$\overline{GZ} = \overline{KN} - \overline{KG} \sin \theta$

FIGURE 28

curve for a particular displacement, a correction must be applied. For the case of righting energy up to a particular heel angle of interest, α:

$$GZ = KN - KG \sin \theta$$

$$\int_0^\alpha GZ d\theta = \int_0^\alpha KN d\theta - \int_0^\alpha KG \sin \theta d\theta$$

$$= \int_0^\alpha KN d\theta - KG (1-\cos \alpha)$$

As in the case of the static stability curve, the correction will always be subtractive. The correction is equal to KG x (1-cos α). A short table of cosines would be necessary to calculate this correction.

5.0 RESULTS OF SHIP VISITS AND WORKSHOPS

5.1 Introduction

In this section the results of the visits and workshops which figure in Table 7 will be evaluated. To perform this evaluation in a mathematically consistent fashion is difficult, since each category of visit (and often each visit within a category) had a different content. Although supervised by the same interviewer, the substance of each interview was strongly influenced by its circumstances and the respondant's background, education, and concerns.

Ship visits ranged from one lasting six hours, to a master and chief officer who were working continuously with their prestow and computer, to twenty minutes with a busy master and chief mate, who had long completed their total range of discharge and ballast calculations, and normally relied on a dedicated loading computer.

5.2 Evaluation of Results

As a first step in the evaluation, the underlying level of knowledge about stability must be analyzed before discussing the officers' opinions. According to the statement of work, the contractor was required to make a determination of the masters' understanding of "...GM, GZ (righting arm), and area under the GZ curve". The examination shown in Appendix 1 (pp. 251-328) was prepared to develop this information, and was administered by MITAGS with contractor assistance. This examination underestimated the masters' intuitive understanding of stability concepts, because (i) the exclusive practical reliance on GM leads officers to ignore or forget alternative presentations of ship's stability, and (ii) recall tests - as opposed to recognition tests - are a very severe criterion of knowledge.

A grading system for comparing test scores, which is also reproduced in Appendix 1 pp. 254-5 was also developed.

Table 45 gives the pattern of formal test scores. The average score was 41, and the standard deviation was 11. In interpreting the scores, it was felt that capacity to judge stability reliably should be reflected in a score of 50. A full understanding of stability criteria should ensure a score of 75. Eleven respondants (of 21) reached the lower criterion, but only one approached the higher one. Analysis of background information could not link performance with particular characteristics of the respondants.

The scores in Table 45 permit several interesting conclusions. In understanding of GM, the dry cargo officers scores "significantly" higher than tanker officers. Significantly in this context means that it is overwhelmingly probable that the difference in score was not a chance, one-time thing, but a genuine difference. This finding may be explained by, and is certainly consistent with, dry cargo officers' emphasis on evaluation of transverse stability. Tanker officers' concern is generally with strength. The officers' scores on the entire test - question 1 excluded - were not "significantly" different, i.e. there is only a remote possibility that retesting would show differences between the two groups. This tends to confirm the hypothesis that dry cargo and tanker officers do not have different levels of ability, but merely different levels of exposure to the computation and use of transverse stability and GM in particular.

Since the formal (unaided recall) examination underestimated officers' understanding of stability concepts, the project staff was forced to look for another, necessarily simple way to determine the extent of officers' comprehension of important stability-related concepts. It

TABLE 45

STABILITY EXAMINATION RESULTS

	RANK	LICENSE	HAUSEPIPE	ACADEMY	SCORE	QUESTION 1 MAXIMUM SCORE 20	QUESTION 2 MAXIMUM SCORE 15	QUESTION 3 MAXIMUM SCORE 20	QUESTION 4 MAXIMUM SCORE 10	QUESTION 5 MAXIMUM SCORE 10	QUESTION 6 MAXIMUM SCORE 5	QUESTION 7 MAXIMUM SCORE 10	QUESTION 8 MAXIMUM SCORE 10
TANKER OFFICERS	C/O	C/O	✓		6	.			1				5
	M	M		✓	14	2		3	1		1	3	4
	2/O	M	✓		15				10	1		2	2
	?	M	✓		20	3		3		3	3	4	4
	M	M	✓		21	7		1	2			6	5
	M	M	✓		28	7		13				4	4
	2/O	M			29	4		3	8	2	2	6	4
	C/O	C/O		✓	49	9	10	8	6	4	2	4	6
	C/O	M		✓	51	4	11	13	8	4	1	6	4
	3/O	3/O		✓	55	15	6	8	4	10	3	4	5
	M	M	✓	✓	57	20	4	14		4	3	4	8
	M	M	✓		65	10	7	20	9	9	3	5	2
DRY CARGO	2/O	C/O	✓		71	18	12	8	10	10	5	4	4
	3/O	M	✓		61	20	9	10	10	4	2	2	4
	2/O	M	✓		57	20	8	9		2	2	10	6
	C/O	C/O	✓		53	9	11	3	9	2	3	6	6
	2/O	M		✓	53	12	7	15	2	4	3	4	6
	C/O	M	✓		52	17	7	12	6	4		2	4
	C/O	M	✓		45	9	4	8	6	3	1	10	4
	2/O	2/O	✓		32	11		8		3		4	6
	M	M		✓	31	11		5	2	1	2	6	4

was decided to make statements which actually had degrees of 'truth value' or absolute correctness, and ask respondants to indicate the extent of their agreement with the statements.

The results from the formal recall examination of stability knowledge can be compared with the results of the exploration of beliefs concerning stability-related vessel behavior in the second workshop (see Appendix 2, p 329). The degree of agreement with the statements indexed the experience-derived knowledge of the respondants.

The percentage agreeing with the statements ranged from 67% to 90%, indicative of a higher level of understanding than that manifested by scores in the recall type test. This supports the idea that ability to deal practically with stability was not accurately estimated in the formal test. It is clear, however, that full understanding of the righting arm presentation of stability is not common, just as the presentation of cross curves is not common. These results cannot be held up to justify continued reliance on the GM criterion of stability, however, any more than they can justify inclusion or substitution of the cross curves for the curve of required GM.

Limited biographical data was collected on the first workshop participants. (Only limited biographical data could be collected, because of time constraints and the need to maintain the officers' confidence in their anonymity.) This biographical data was subsequently analyzed and compared to test scores and other data. It established that there was no significant difference between the practical knowledge of stability of college graduates and 'hawsepipe' officers, tanker officers and

dry cargo officers, masters and 'other ranks', or any other logical groupings. This finding was used to justify combining all ranks' interview and workshop results.

The sample sizes obtainable even at MITAGS were determined to be too small to allow multivariate analysis of responses. Therefore, the *general* validity of the results of the present study cannot depend on the representativeness of the respondants but relies instead on the propriety of naturalistic observation and interview techniques for developing recommendations of the type discussed in Section 6.0.

The sample included only volunteers, and was preponderantly composed of officers undertaking voluntary professional studies. It would be reasonable to assume that they represented a more interested and dedicated element of the seafaring population than average. However, no evidence was discovered which suggested that the sample was *atypical* in temperament, age distribution, experience, ability, or any other characteristic. Some geographic sampling bias certainly exists: the study did not treat the West Coast thoroughly, for economic and other reasons, such as the preponderance of maritime educational institutions and corporate offices on the East and Gulf coasts. Probably the sample also under-represents West Coast-domiciled officers. However, the estimated geographical mobility of seafarers is such that project staff cannot see any systematic distortion resulting from this factor.

The impact of the contents of the study instruments and the reactive effects of the interviewers on the validity of the results of the present study were estimated and discounted in developing the recommendations. The project staff does not feel that systematic or

significant distortions are present in their representation of the responses.

There has been a noticeable difference between the responses made in training institutions, in shore terminals, and aboard ship. Respondants at MITAGS and the academies were dissatisfied, above all, with the *approach* of existing T&S booklets, which were claimed to include too many inappropriate simplifying assumptions and insufficient guidance in basic principles. Terminal personnel evidently made by far the most detailed use of the booklet and were most aware of the extent of inaccuracies and omissions in the booklets. The shipboard responses were more guarded, and indicated less item-by-item knowledge of, and less dissatisfaction with, the format and contents of the trim and stability booklet. In line with this observation, it was noted that serving mariners who had taught stability were the most critical, and offered more suggestions for improvement of the booklet. One explanation of this lies in the tendency of the ship's officers to use their alternative sources of information, and own methods and forms for calculating stability.

An additional explanation of these differences may arise from the tendency for the consideration of stability aboard ship and at loading terminals to be restricted to the functions and aspects which are legally and operationally necessary, whereas at the training institutions, respondants - students as well as staff - are considering the requirements for quick, accurate, and *extensive* stability information, in a more deliberate manner, with the advantage of recent exposure to the principles and to a teaching environment.

5.3 Results of Interviews and Workshops

Table 46 lists the major findings of the project with associated percentages. Although there was a definite situational bias in the responses, as previously noted, there is still an acceptable degree of external consistency - with results of the contractor's previous investigation - and internal consistency. For example, the percentages requiring improved graphic standards for the booklet ranged from 79% aboard ship (least critical group), through 86% in industry positions (moderately critical), to 100% at MITAGS (most reflective and critical).

The most striking fact is the evident practical irrelevance of the booklet and the low degree of ship officer/operator satisfaction with existing booklets. Much of the booklet's contents appear to be less useful than files, capacity plans, and other stability-related items aboard ship. The calculation forms supplied are not used in the majority of cases. Eighty-eight percent of respondants would have liked the forms supplied to the ships to be commercially printed regardless of who developed them. The reliability and completeness of capacities and centers data is approved by only 14% of industry contacts, and 17% of participants in the workshops, while mariners interviewed aboard their vessels were uniformly critical of the accuracy of this component.

Proposed changes in the format and/or contents of the T&S booklet will have to be brought to the attention of mariners before they can raise the perceived utility and suitability of the booklet. One way of doing this, which was suggested during some of the ship visits, would be to involve the masters and chief engineers in the development and verification of the booklet. Senior officers generally stand by new vessels during the

TABLE 46

SUMMARY OF OPINIONS

SHIP VISITS

Percentage using entire booklet - 0%

Percentage using direct exerpts of booklet - 40%

Percentages of booklet non-users using various alternatives:

files, capacity plan, loading manual - 40%

electronic aids - 60%

Percentage using sample conditions - 0%

Percentage considering booklet bending moment calculations satisfactory and using same - 0%

Percentage considering space and capacity data in booklet complete, accurate, and using same - 0%

Percentage considering instructions/explanations generally inadequate in number/detail - 27%

Percentage considering reproduction inadequate - 79%

Percentage considering trim table inaccurate - 57%

Percentage using table of gain in GM with confidence - 0%

Percentage finding the language of instruction too complex - 34%

INDUSTRY INTERVIEWS

Percentage positively satisfied with their booklet - 14%

Percentage supplying "competing" material e.g. deck officer's handbook, loading manual, etc. - 100%

Percentage advocating sample conditions in their present form - 0%

Percentage approving accuracy and layout of capacities and centers data in present form - 14%

Percentage considering reproduction inadequate - 86%

Percentage currently developing new/experimental treatments of aspects of stability/strength determinations - 40%

WORKSHOPS

Percentage viewing T&S booklet as a safety device - 58%

Percentage in favor of vessel type standardization of booklet - 100%

Percentage requiring better reproduction - 100%

Percentage requiring commercially-printed calculation forms - 88%

Percentage requiring fewer/more realistic examples respectively - 50%/95%

Percentage requiring specification and referencing of underlying safety standards - 83%

Percentage requiring procedural and operating instructions - 100% - in step by step format - 85%

Percentage seeing discrepancies between ship/shore cargo weights and centers - 83%

building. None of the respondants with such standing-by experience had seen the draft T&S booklet before the inclining experiment, or had instruction and practice in using it.

Tables 47 and 48 indicate in detail the preferences expressed by masters and mates, during the preliminary series of nine depth interviews, and shipboard interviews. Table 49 summarizes the industry consensus. These tables give an impression of the divergence in requirements between various vessel types.

TABLE 47

PREFERENCES EXPRESSED IN DEPTH INTERVIEWS

POSSIBLE REVISIONS \ INTERVIEWEES	DRY CARGO MASTER	CONTAINER MASTER	LINER MASTER	TANKER CHIEF OFFICER	LINER MASTER	LINER MASTER	CONTAINER MASTER	LINER MASTER	LINER MASTER
Additional Content									
Cross Curves	✓						✓		
curves of form	✓								
additional instructions	✓				✓	✓			
additional dimensions in vessel particulars	✓				✓				
dwt & displacement scales	✓								
graph/table of maximum vertical moment		✓	✓						
seakeeping information			✓						
damage stability information									
More Completeness and Accuracy									
cargo capacity and centers data	✓	✓		✓			✓	✓	✓
light displacement	✓								
free surface effect table				✓					
Deletions									
examples				✓	✓				
Format									
simplification		✓	✓		✓	✓	✓	✓	✓
tabular wher possible	✓			✓			✓	✓	
graphical		✓							
fewer intervals - interpolate on hand-held calculator				✓					✓

TABLE 48 PREFERENCES EXPRESSED DURING SHIPBOARD INTERVIEWS

QUESTIONS / RESPONDANTS' VESSEL TYPE	Parcel Tanker	Container Vessel	Parcel Tanker
1. Has the table of ship's principal characteristics been useful to you in *calculating* stability?	Booklet never used.	Booklet never used.	Booklet lost.
2. Has the table of lightship condition been useful to you in *calculating* stability.	"	"	"
3. What is your opinion of the operating and general instructions which are included in every T&S booklet?	"	"	"
4. The graph of required GM reflects several stability criteria; there may be more than one curve of required GM. Is the graph explained to your satisfaction?	N/A	Clear - one curve	"
5. Are the graphs and tables of the T&S booklet reproduced adequately?*	3	3	"
6. Is the trim table of use to you in planning loading/weight transfers?	UAE	US	"
7. Is the table of gain in GM of use to you in planning loadings/weight transfers?	N/A	Useless; see remarks	"
8. Have the sample loading conditions been useful to you; How many do you like to see included in the booklet?	No	No	No - none
9. What is your opinion of the bending moment calculation/calculation form included in the T&S booklet?	UAE	computer program	too spread out, vague
10. Do you refer to the T&S booklet for cargo space and capacity data <u>or</u> do you use the ship's loading manual?	calibration tabs & capacity plan	"	"
11. Does it seem important to you that all tables and graphs should be oriented the same way - that is, laid out on the page so that they all read down, or all read across?	indifferent; booklet never used	indifferent; booklet never used	-
12. Would you like more diagrams, ship profiles, or other graphical aids in the T&S booklet?	"	"	-
<u>REMARKS</u>	extreme time pressure on operations	needs: total impact each tank, table of true listed draft, good trim table, perm. ballast effect annoying (7' drag)	fixed run: done from previous voyages-booklet lost, no longer accurate

*<u>1-5 scale</u>: 1. excellent
2. all figures and text legible
3. mostly legible
4. figures and text intermittently illegible
5. virtually illegible

<u>LEGEND</u>:
NA = not applicable
US = unsatisfactory
UAE = used as exempt
NSB = not supplied in booklet

TABLE 48 (continued)

QUESTIONS \ RESPONDANTS' VESSEL TYPE	Small Bulk Carrier	Container Vessel	Container Vessel
1. Has the table of ship's principal characteristics been useful to you in *calculating* stability?	not useful	not useful	not useful
2. Has the table of lightship condition been useful to you in *calculating* stability	"	"	"
3. What is your opinion of the operating and general instructions which are included in every T&S booklet?	sources of figures not explained; no expl. of vol. heeling momts	virtually no instructions	obscure, too long
4. The graph of required GM reflects several stability criteria; there may be more than one curve of required GM. Is the graph explained to your satisfaction?	one graph; clear	RA criterion	-
5. Are the graphs and tables of the T&S booklet reproduced adequately?*	3	4	4
6. Is the trim table of use to you in planning loading/weight transfers?	UAE; guideline	yes; 100T good figure	ballpark
7. Is the table of gain in GM of use to you in planning loadings/weight transfers?	NA	NA	no
8. Have the sample loading conditions been useful to you; How many do you like to see included in the booklet?	no; requires improvement & explanation	no examples; files used	no; none
9. What is your opinion of the bending moment calculation/calculation form included in the T&S booklet?	N/A	no BM calc. supplied in booklet	form not useful
10. Do you refer to the T&S booklet for cargo space and capacity data <u>or</u> do you use the ship's loading manual?	capacity plan used	capacity plans & calibration tables	shore data and forms used
11. Does it seem important to you that all tables and graphs should be oriented the same way - that is, laid out on the page so that they all read down, or all read across?	indifferent	-	yes
12. Would you like more diagrams, ship profiles, or other graphical aids in the T&S booklet?	"	-	yes
REMARKS	grain ex; why not use NCB form	present booklet NSB-all work done from 1st principles adversarial view of CG	BM calc. should be included only where a bending constraint graphical aids would help faster understanding

*1-5 scale:
1. excellent
2. all figures and text legible
3. mostly legible
4. figures and text intermittently illegible
5. virtually illegible

LEGEND:
NA = not applicable
US = unsatisfactory
UAE = used as exerpt
NSB = not supplied in booklet

TABLE 48 (continued)

QUESTIONS \ RESPONDANTS' VESSEL TYPE	Product Tanker	Product Tanker	Shelterdeck Vessel (Bulk Carrier)
1. Has the table of ship's principal characteristics been useful to you in *calculating* stability?	Booklet never used.	Booklet never used.	Booklet never used.
2. Has the table of lightship condition been useful to you in *calculating* stability.	"	"	"
3. What is your opinion of the operating and general instructions which are included in every T&S booklet?	obscure; too long	"	language too complex
4. The graph of required GM reflects several stability criteria; there may be more than one curve of required GM. Is the graph explained to your satisfaction?	N/A	N/A	satisfactory
5. Are the graphs and tables of the T&S booklet reproduced adequately?*	3	3	3
6. Is the trim table of use to you in planning loading/weight transfers?	No; Koehler sliderule	no	yes
7. Is the table of gain in GM of use to you in planning loadings/weight transfers?	N/A	N/A	N/A
8. Have the sample loading conditions been useful to you; How many do you like to see included in the booklet?	no; indifferent	no; files used	no; files used
9. What is your opinion of the bending moment calculation/calculation form included in the T&S booklet?	Loadicator used, not booklet form	Loadicator used not booklet form	N/A
10. Do you refer to the T&S booklet for cargo space and capacity data <u>or</u> do you use the ship's loading manual?	capacity plan & calibration tables	capacity plan	capacity plan
11. Does it seem important to you that all tables and graphs should be oriented the same way - that is, laid out on the page so that they all read down, or all read across?	Booklet never used; indifferent	Booklet never used; indifferent	Booklet never used; indifferent
12. Would you like more diagrams, ship profiles, or other graphical aids in the T&S booklet?	"	"	"
REMARKS *1-5 scale: 1. excellent 2. all figures and text legible 3. mostly legible 4. figures and text intermittently illegible 5. virtually illegible	RHC should be available to computer correct trim during topping off		simple languages desired

LEGEND:
NA = not applicable
US = unsatisfactory
UAE = used as exerpt
NSB = not supplied in booklet

TABLE 48 (continued)

QUESTIONS / RESPONDANTS' VESSTL TYPE	LASH	SEABEE	Heavy Lift
1. Has the table of ship's principal characteristics been useful to you in *calculating* stability?	Booklet never used	Read only once; not useful	not useful
2. Has the table of lightship condition been useful to you in *calculating* stability.	"	"	table of lightship inacc. & req'd revision
3. What is your opinion of the operating and general instructions which are included in every T&S booklet?	"	adequate but explanations & sources desired	language too complex
4. The graph of required GM reflects several stability criteria; there may be more than one curve of required GM. Is the graph explained to your satisfaction?		no: highly ambiguous	no; ambiguous + lack of direction
5. Are the graphs and tables of the T&S booklet reproduced adequately?*	3	3	3
6. Is the trim table of use to you in planning loading/weight transfers?	no	yes; rough results only required	no
7. Is the table of gain in GM of use to you in planning loadings/weight transfers?	?	no; used to incr. GM but never for sailing	N/A
8. Have the sample loading conditions been useful to you; How many do you like to see included in the booklet?	no	no; unrealistic	no, prefer explanations
9. What is your opinion of the bending moment calculation/calculation form included in the T&S booklet?	?	no BM calc. in booklet	N/A
10. Do you refer to the T&S booklet for cargo space and capacity data or do you use the ship's loading manual?	shore figures used extensively	shore figures used extensively	loading manual
11. Does it seem important to you that all tables and graphs should be oriented the same way - that is, laid out on the page so that they all read down, or all read across?	Booklet never used	yes	yes
12. Would you like more diagrams, ship profiles, or other graphical aids in the T&S booklet?	Booklet never used	yes	yes
REMARKS	table of drafts for listed condition layout poor: separation of info req'd together, booklet not to hand.	needed x table for converting Aranson to quarter drafts Lykes added useful "change in displacement with change in trim" table	needed x table for converting Aranson to quarter drafts HHC programs for integrating areas under RA curve required

*1-5 scale:
1. excellent
2. all figures and text legible
3. mostly legible
4. figures and text intermittently illegible
5. virtually illegible

LEGEND:
NA = not applicable
US = unsatisfactory
UAE = used as exerpt
NSB = not supplied in booklet

TABLE 46 (continued)

QUESTIONS \ RESPONDANTS' VESSEL TYPE	Container Vessel (Conversions)	Container Vessel (Conversions)	RO/RO
1. Has the table of ship's principal characteristics been useful to you in *calculating* stability?	not used	not used	not used
2. Has the table of lightship condition been useful to you in *calculating* stability.	"	"	"
3. What is your opinion of the operating and general instructions which are included in every T&S booklet?	complex language in long form inst. some ambiguity in oper. inst.	complex language in long form inst. some ambiguity in oper. inst.	very clearly written
4. The graph of required GM reflects several stability criteria; there may be more than one curve of required GM. Is the graph explained to your satisfaction?	clear; one curve	clear; one curve	very clear; tabular format
5. Are the graphs and tables of the T&S booklet reproduced adequately?*	3	3	1
6. Is the trim table of use to you in planning loading/weight transfers?	UAE	UAE	UAE
7. Is the table of gain in GM of use to you in planning loadings/weight transfers?	US	US	estimation & planning
8. Have the sample loading conditions been useful to you; How many do you like to see included in the booklet?	no; indifferent	no; indifferent	fixed trade; useful in learning to use booklets
9. What is your opinion of the bending moment calculation/calculation form included in the T&S booklet?	not supplied in T&S booklet	not supplied in T&S booklet	not supplied in T&S booklet
10. Do you refer to the T&S booklet for cargo space and capacity data or do you use the ship's loading manual?	computer program used	computer program used	no
11. Does it seem important to you that all tables and graphs should be oriented the same way - that is, laid out on the page so that they all read down, or all read across?	indifferent	indifferent	no
12. Would you like more diagrams, ship profiles, or other graphical aids in the T&S booklet?	indifferent	indifferent	no
REMARKS			v/1 on fixed run; master, mate highly satisfied with existing booklet

*1-5 scale:
1. excellent
2. all figures and text legible
3. mostly legible
4. figures and text intermittently illegible
5. virtually illegible

LEGEND:
NA = not applicable
US = unsatisfactory
UAE = used as exe[illegible]
NSB = not supplied in booklet

TABLE 48 (continued)

QUESTIONS \ RESPONDANTS' VESSEL TYPE	LNGC		
1. Has the table of ship's principal characteristics been useful to you in *calculating* stability?	-		
2. Has the table of lightship condition been useful to you in *calculating* stability.	-		
3. What is your opinion of the operating and general instructions which are included in every T&S booklet?	-		
4. The graph of required GM reflects several stability criteria; there may be more than one curve of required GM. Is the graph explained to your satisfaction?	N/A -		
5. Are the graphs and tables of the T&S booklet reproduced adequately?*	4		
6. Is the trim table of use to you in planning loading/weight transfers?	not supplied		
7. Is the table of gain in GM of use to you in planning loadings/weight transfers?	N/A		
8. Have the sample loading conditions been useful to you; How many do you like to see included in the booklet?	no; files used		
9. What is your opinion of the bending moment calculation/calculation form included in the T&S booklet?	not supplied in booklet		
10. Do you refer to the T&S booklet for cargo space and capacity data <u>or</u> do you use the ship's loading manual?	indifferent		
11. Does it seem important to you that all tables and graphs should be oriented the same way - that is, laid out on the page so that they all read down, or all read across?	indifferent		
12. Would you like more diagrams, ship profiles, or other graphical aids in the T&S booklet?	indifferent		
<u>REMARKS</u> *<u>1-5 scale</u>: 1. excellent 2. all figures and text legible 3. mostly legible 4. figures and text intermittently illegible 5. virtually illegible	largely fixed run, free use of electronic aids. capability of ships' staff to draw RA curve not ascertained		
<u>LEGEND</u>: NA = not applicable US = unsatisfactory UAE = used as exerpt NSB = not supplied in booklet			

TABLE 49

INDUSTRY CONSENSUS

1. Usefulness of table of principal characteristics
   Not useful in calculations.

2. Lightship weight and details
   Correct lightship important in weight-limited operations; LASH operators wished to use annually increasing lightship weight - others "effective lightship" concept.

3. Instructions
   Procedural instructions should be attached to relevant tables.

4. Required GM Curve
   GM graph to be tabularized, if unique, and added to hydrostatics table; intervals to be better related to behavior of curve (i.e. closer where curves inflect) and suited to interpolation using hand-held calculator.

5. Reproduction
   Uniformly regarded as needing improvement, first in legibility, second in clarity of use and intent.

6. Trim Table
   100 tons table was used for small transfers, some electronic aid for managing full scale operations (several operators were highly critical of accuracy. NB: LCF drafts desired, to eliminate one step in first principles calculation of trim).

7. Gain in GM Table
   Such an (accurate) table desired, but total information was requied on effects of filling empty tanks.

8. Loading Conditions
   Generally felt to be unrealistic and therefore of very limited use. It was pointed out that the conditions were often not really worked out, not referenced properly to body of booklet, did not display reasoning; should be completed for short form and long form where both are supplied.

9. BM Calculation
   Oversimplified first principles and computer should be used.

10. Cargo Space and Capacity Data
    More details required, in a uniform layout for ship and shore.

11. Orientation
    Indifferent.

12. Diagrams, Graphs, Etc.
    Yes' graphs, headings, etc., interspersed in text.

6.0 RECOMMENDATIONS

6.1 Introduction

Operating personnel of all vessel types, as well as the sponsors of the study, felt that one purpose of the trim and stability booklet was to ensure safe and legal operation of the vessel. It is clear, however, that existing historically developed standards and specifications do not result in uniformly usable and informative material. Not one participant in the study claimed to use the booklet as an operational reference. Nearly all used other sources, often preferring to make their own forms and reference guides.

A major contributing factor in this situation is that the existing booklets require more concentration to use than is required by the problem they address. As such, they are dysfunctional when used in the disruptive circumstances surrounding the loading of all vessels. T&S booklets will remain an underutilized resource until they are simplified and made to yield faster, yet accurate, results.

To discharge its safety function, the booklet must contain (i) the routine and specific operating instructions and the capacity data needed to develop safe operations sequences which comply with load line and inspection requirements, together with (ii) methods to enable the master to compute, check and assess his stability, trim, and strength with minimal calculation. If stress considerations govern vessel operation, then longitudinal strength information and calculations methods must be included in the booklet, whether or not they are duplicated in the ABS loading manual. If the booklet does not contain <u>all</u> the governing information, then it cannot act to ensure vessel safety. Bending moments are

often the primary constraint on loading, superseding GM, and the two are aspects of the same problem.

If the booklet is to increase the efficiency of vessel operations and assist new officers, more and better instructions are required. These should display loading options and results, and be fully referenced in the body of the booklet. The present form of sample conditions pertains to these functions, but does not satisfy officers' needs for guidance. Additional information related to the vessel's special trade and/or unusual cargoes should be compiled in a standardized format and relegated to a subsidiary location determined by its bulk. Grain instructions, for example, might be either an appendix, for a LASH vessel, or a separate booklet, for a tanker. The location and availability of further stability-related material should be clear in the T&S booklet.

The range of vessels examined did not suggest that existing or foreseeable commercial hull forms require markedly different T&S booklets. The hydrostatics may change in a novel way, but this can be dealt with by including the curves of form and closing up the intervals on the hydrostatics tabulation. Hull forms may make conventionally placed draft marks difficult to read when the vessel is alongside, but this, too, is a surmountable problem. Heavy lift vessels need to perform an elaborate righting arm-heeling arm calculation before major lifts, but this is additional to ascertaining sailing GM and drafts, and implicitly dealt with in the discussion of cross curves.

6.2 General Recommendations

All functions of the trim and stability book could be discharged by a shortened, reorganized book.

It is clear from the review of their opinions, and analysis of 'mate's forms', that in general masters and mates are interested in precise details of the vessel's draft, trim, and overhead clearance, but only need to establish that they are within safe *ranges* of strength and stability. In line with this, it is proposed that there should be more emphasis on Van Der Ham diagrams and tables of maximum vertical moments - i.e. quick 'envelope' techniques - to guide cargo planning and operations. A Van Der Ham gives an accurate draft while a moments table demarcates safe loading ranges. In principle, these two could replace the traditional hydrostatics-based approach.

Table 50 summarizes the operations required to determine drafts, trim and stability using the current hydrostatics-base and the deadweight moment approaches. The latter is equally applicable to dry cargo and tank vessels. It offers significant time savings and eliminates much arithmetic effort, compared to computation from the designers' hydrostatic information. Such an abrupt break with traditional appearances and familiar methods of calculation would entail some risks and meet resistance, however. A revised booklet incorporating the moments tables as means to quick determination of trim and stability, and reorganizing the traditional presentation of information, would meet users' traditional and ultimate needs. It would also, most importantly, be consistent with the probable and desirable trend toward automated calculation of stability.

Electronic Aids

Nearly all masters and mates interviewed made extensive use of electronic aids to cargo operations. Tankers employed various types of analog loading computers,

TABLE 50

DETERMINATION OF DRAFT, TRIM, AND STABILITY

ITEM	PROCEDURE: TYPICAL METHOD	PROCEDURE: "DEADWEIGHT MOMENT" METHOD
Loading Summary	1. Enter weights of cargo and consumables	1. Enter weights of cargo and consumables
	2. Multiply weights by longitudinal, vertical (and transverse, if desired) centers to get moments	2. Multiply weights by longitudinal, vertical (and transverse, if desired) centers to get moments
	3. Determine appropriate free surface moments (from capacity tables)	3. Determine appropriate free surface moments (from capacity tables)
	4. Sum weights plus lightship to get displacement	4. Sum weights to get total deadweight
	5. Sum moments plus lightship moment to get moment of displacement (longitudinal, vertical, transverse)	5. Sum moments to get moment of deadweight (longitudinal, vertical, transverse)
	6. Divide moments by displacement to get LCG, VCG, TCG	
Trim and Draft Determination	7. Enter table or graph of hydrostatics with displacement and read off: a. mean draft or LCF draft b. LCB c. MTI d. LCF	6. Enter Van der Ham diagram with deadweight and longitudinal deadweight moment and read off forward and aft drafts
	8. Solve for trim: Trim (feet) = Displ x (LCG-LCB)/(MTIx12)	

TABLE 50

DETERMINATION OF DRAFT, TRIM, AND STABILITY

(continued)

ITEM	PROCEDURE: TYPICAL METHOD	PROCEDURE: "DEADWEIGHT MOMENT" METHOD
	9. Determine forward and aft drafts:* $T_{Fwd} = T_{LCF} + (\frac{LCF}{LBP}) \times Trim$ $T_{Aft} = T_{LCF} - (\frac{LBP-LCF}{LBP}) \times Trim$ *Note: longitudinal centers referenced to forward perpendicular	
Stability Determination	10. Enter table or graph of hydrostatics with displacement and read off KM. 11. Sum free surface moments in loading table, divide by displacement to determine free surface correction (FSC) 12. Compute available GM: $GM_a = KM - VCG - FSC$ 13. Enter graph of required GM with mean draft and check adequacy of available GM	7. Sum free surface moments and add to vertical deadweight moment to obtain corrected value. 8. Enter graph of maximum permissible vertical deadweight moment with deadweight and check that actual does not exceed this value
List Determination	14. Calculate List: List (degrees) = 57.3 x TCG/GM	9. Enter graph of list with deadweight and transverse deadweight moment and read off heel angle.

which gave displacement, trim, and longitudinal strength. An attachment gave transverse stability, where this was necessitated by ballast tank location. Dry cargo and container vessels used microcomputers and/or simple mechanical or electronic calculators, often with printout. As will be discussed in Section 6.4, analog computers are more accurate and faster in determining bending moments, while (digital) microcomputers are better for adding weights and obtaining vertical moments. The different performances to be expected from the two types of electronic aids are not well understood by many users. The resultant level of dissatisfaction fuels the demand for quick methods of determining trim and GM. Very few respondants employed a hand-held calculator in conjunction with their computer, other than to review prestows and obtain initial cargo weights.

The following are some desired features of analog computers which would be compatible with an improved trim and stability booklet. Officers would like to have a record of calculations, even though printout devices were the least reliable component of any electronic configuration discussed. They also like to see the inputs preserved, so that input errors can be checked as well as the printout quickly reviewed. Thumbwheel (potentiometer) rather than keyboard inputs facilitate this. A facility for converting barrels of cargo to net barrels at API 60°, m^3, ft^3, and long tons would complement the automation of the trim and strength calculation. Generally, officers would like to be able to input the density of the dockwater, in order to obtain sailing as well as deep sea drafts. They are also concerned wtih draft at the marks, rather than at the perpendiculars, in order to comply with load line requirements. Finally, there is an increasing

desire to understand the phenomena of bending moment and shear force, and officers would like to see the curves displayed for each proposed loading.

Desired features of microprocessor systems generally related to speed of calculation. Microprocessor users frequently complained of the slowness of their programs. Although these systems are, indeed, intrinsically slower in computing bending moments and shear forces than analog computers, correct sizing of the equipment and an appropriate configuration can produce very fast results. The interactive programs reviewed during this study had facilities for retrieving user errors and were inherently resistant to errors arising from the unfavorable settings of T&S calculations.

6.3 Suggested Contents of Optimum Trim and Stability Booklet

The optimized version of the T&S booklet was developed by asking what outputs are required from the calculations, what are the arithmetically simplest, most error-free ways of arriving at these, and what descriptive information about the ship is required to support them.

Mariners' recommendations were discussed in Section 5.0, but it is necessary to reiterate here that stability assessment is not such a major task for masters and mates that it has become a focus of their best efforts to simplify and foolproof the process.

The optimized T&S booklet still includes a conventional hydrostatics presentation. The principal changes would be (i) improvement in instructions, (ii) clearer, more legible presentation of tables, (iii) provision of better calculation forms in a separate,

TABLE 51 RECOMMENDED TABLE OF CONTENTS OF T&S BOOKLETS

Page No.

Cover
Introduction
TABLE OF CONTENTS

Table of Contents

Instructions
  General Instructions and Conversion Factors
  Operational Guidance
  Flume Tank Data and Instructions
Cargo Space and Capacity Data
  Summary of Cargo Spaces, Centers, and Weights
  Plan, Profiles, and Elevation of Vessel Showing Cargo Spaces
Consolidated Tankage Table: Capacities, Centers, Operational Effects
  Cargo Tanks
  Ballast Tanks
  Fuel and Diesel Oil Tanks
  Miscellaneous Tanks
  Flume and/or Other Stabilizing Tanks
Combined Table of Hydrostatics, Deadweight, and Required GM
Reduced-scale "Long" Form, with Instructions & Supporting Worksheet
Table of Maximum Allowable Virtual Vertical Moments
Van der Ham Diagram
Draft Particulars
  Draft Diagrams and Stern Profile
  Draft and Freeboard Particulars for Fresh and Salt Water
Cross Curves of Stability
  Instructions for Plotting Statical Stability Curve
  Interpreting the Curve for Seaway Conditions
Longitudinal Stress Determination
  Instructions for Assessing Longitudinal Strength
  Table of Bending Moments
Appendices
  A - Table of Vessel's Principal Characteristics and Details of Effective Lightship Condition
    Name, Official Number, Date and Place of Building, Principal Dimensions
    Definition of Lightship Used in Booklet
    Lightship Weights and Centers of Gravity
    References to Plans and Drawings
  B - Sample Loading Conditions
    Cargo Conditions
    Suggested Light Ballast
    Suggested Gale Ballast
  C - Damage Stability Information
    Source and Governing Criteria

commercially-printed format, and (iv) inclusion of vertical and longitudinal moments tables. The overall organization and page layouts of the booklet will reflect the sequence of computations. The assumptions, sources, and estimated reliability of each component must be explicit.

Table 51 gives the recommended table of contents. The International Association of Classification Societies approach has been adopted, i.e. formulating a general table of contents. The general required characteristics of each component are specified in pp 183 to 222, in the order in which they appear in the suggested booklet. Some components may appear only in an abbreviated form on particular types of vessels, but the booklet organization should nevertheless be very similar. The development of three or four parallel forms of booklets with variable contents would revert in short order to the present unstandardized situation. The overall recommendations for graphic standards are discussed in Section 6.5. Sections 6.3.1-6.3.2 address the content and presentation of each of the items.

6.3.1 Table of Contents

The volume of reference materials aboard ship is large, and growing. Since it is important that each reference is as quick and easy to use as possible, an explicit table of contents is required. An introduction which explains the structure of the booklet to the user (see below) is well worth an extra page. The example given is not necessarily organized in the best fashion, but the structure of the book is very clear. It provides an incentive for the officers to read sections A-D at once and peruse the Appendices later, when time permits.

> This manual is provided for the guidance of the Master in planning the loading of the vessel.
>
> For convenience, this booklet is divided according to subject into sections designated with capital letters as "SECTION A", "SECTION B", etc. and sub-headings within sections are designated with numerals such as "Item A-4", "Item B-2", etc.
>
> The first part, SECTION A through SECTION D, contains all necessary instructions for the normal operation of the vessel in a conservatively safe manner.
>
> The second part (APPENDIX I), SECTION E through Section G, contains:
>
> a. Instructions for the calculation of stability and longitudinal strength in the event of failure or malfunction of the Loadmaster.
>
> b. Data for stability calculations.
>
> The third part (APPENDIX II), SECTION H presents the various calculated characteristics of a number of typical conditions of loading.

The table of contents should account for *every page* of the booklet, including inner paper covers. The items should be arranged in columns 3" in width, with judicious use of underlining, indentation, and spacing to lead the eye to the correct page number. If more than one page is necessary, appendices should be grouped on a separate page.

6.3.2 General and Operating Instructions

The mariners interviewed considered the lack of explicit operational guidance to be a severe failing of the booklet. Even if it is desired to keep the size of the trim and stability booklet to the minimum consistent with safety, there is still a need for detailed guidance in safe vessel operation. It cannot be over-emphasized that it is entirely appropriate and nearly universally

requested that the general instructions promote the user's understanding of his vessel. The existing instructions too frequently are merely a guide to use of the calculation forms, which is not generally necessary, and certainly has no reference value once the computation has been mastered. Such guidance could be built into the forms, and a more useful selection of observations, requirements, etc. substituted in the T&S booklet.

The general and operating instructions fall into two sections, clearly distinguished: one group of instructions which is necessary to interpret the guidance materials supplied and a much larger group which is required to enable the operator to make the best use of his vessel's capabilities. The basic instructions should explain the criteria governing operations, orient the user with respect to the 'outfit' of stability items aboard his vessel, and give a general procedural instruction which is complementary to the instructions-for-use printed on each table or graph required to be used in the process of judging stability, trim, and stress. Procedural instructions should identify inputs needed to perform the calculations, transformations of inputs if needed, and the sequence of calculations. Formulas, aides-memoires, and implicit guidance should be incorporated in the calculation forms and not repeated in the general instructions. A clearly set-off paragraph can be included, giving units and conversion factors used in the booklet.

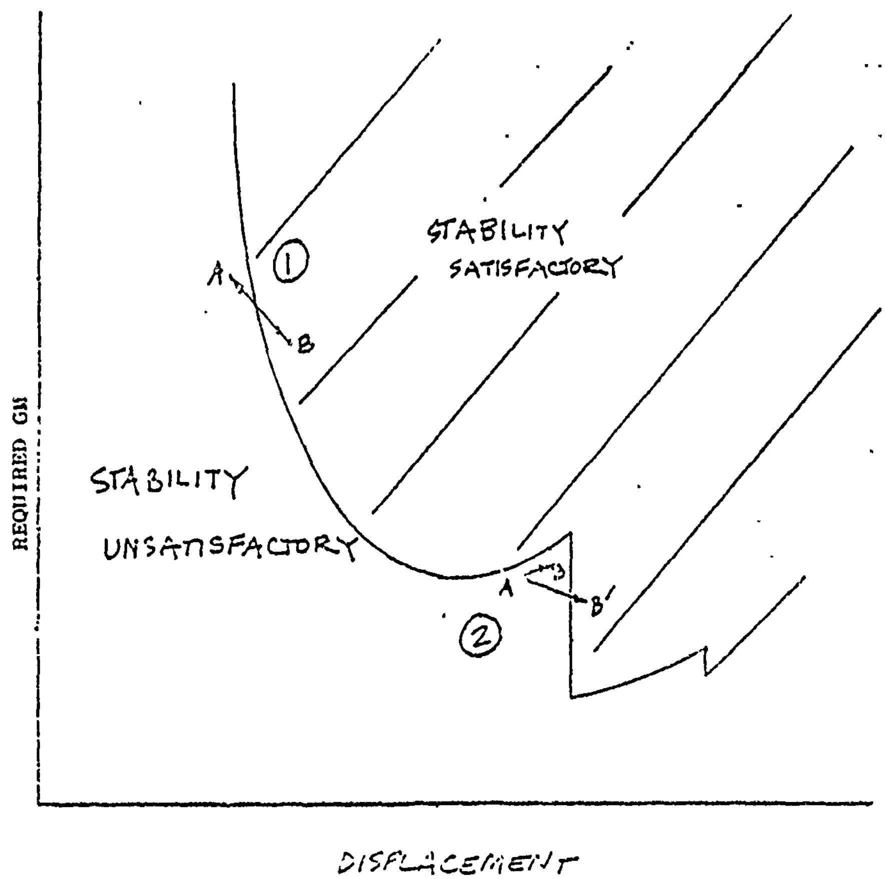
Some operating instructions must be considered as basic, e.g. suggested ballasting and burn-out sequences, with explicit consideration of transient effects and necessary countermeasures. These should be supported by profile, plan, elevation sketches indicating locations

of tanks and direction and magnitude of effect on vessel behavior. The conventional curve of required GM should be supported by instructions on how to effect necessary improvements to a marginal situation. This is particularly necessary if the curve has plateaus, where ambiguity arises unless the GM curve is explained in conjunction with the operating instructions. See Figure 29. Many officers have generalized ideas about the effects of weights below the waterline, or at the ends of the vessel, which do not produce the intended effects on all vessels. These suggested instructions will avoid any problems arising from these ideas, and over time, will correct them.

<u>Additional Presentations and Instructions</u>

In this section, there is scope for simplified presentations of important aspects of vessel behavior, such as rolling period. The period is the most important parameter in rolling behavior, and for technically unsophisticated personnel, it is the easiest to understand. The required GM curve may be translated into a maximum rolling period curve for each vessel. The rolling period curve should indicate roll as a function of displacement and GM, and the graph should be supported by an explanation of the relationship between vessel's speed and sea state. This would support the current practice of checking GM frequently by roll, and would ensure that effects of at-sea transfers were assessed.

Figure 30 gives an interesting presentation of the interaction of a vessel's rolling period and the speed and angle of attack into a sea. It offers the master the information required to avoid synchrony by slowing down and/or changing course. While it is inapplicable in a



1 A to B: GM decreased, stability becomes satisfactory.
B to A: GM increased, stability becomes unsatisfactory.

2 A to B: GM increased by more than original shortfall. of available from required, but stability remains unsatisfactory.
A to B': GM decreased, stability becomes satisfactory.

FIGURE 29 GM CURVE WITH NOTE OF AMBIGUITIES REQUIRING EXPLANATION IN THE BOOKLET

To Use: Draw two lines, parallel to AA', from the intersection of the wave length lines with the applicable roll period to the semicircle representing the intended speed. The zone cut off indicates the speeds at which heavy rolling occurs and the course changes which can be made to reduce it.

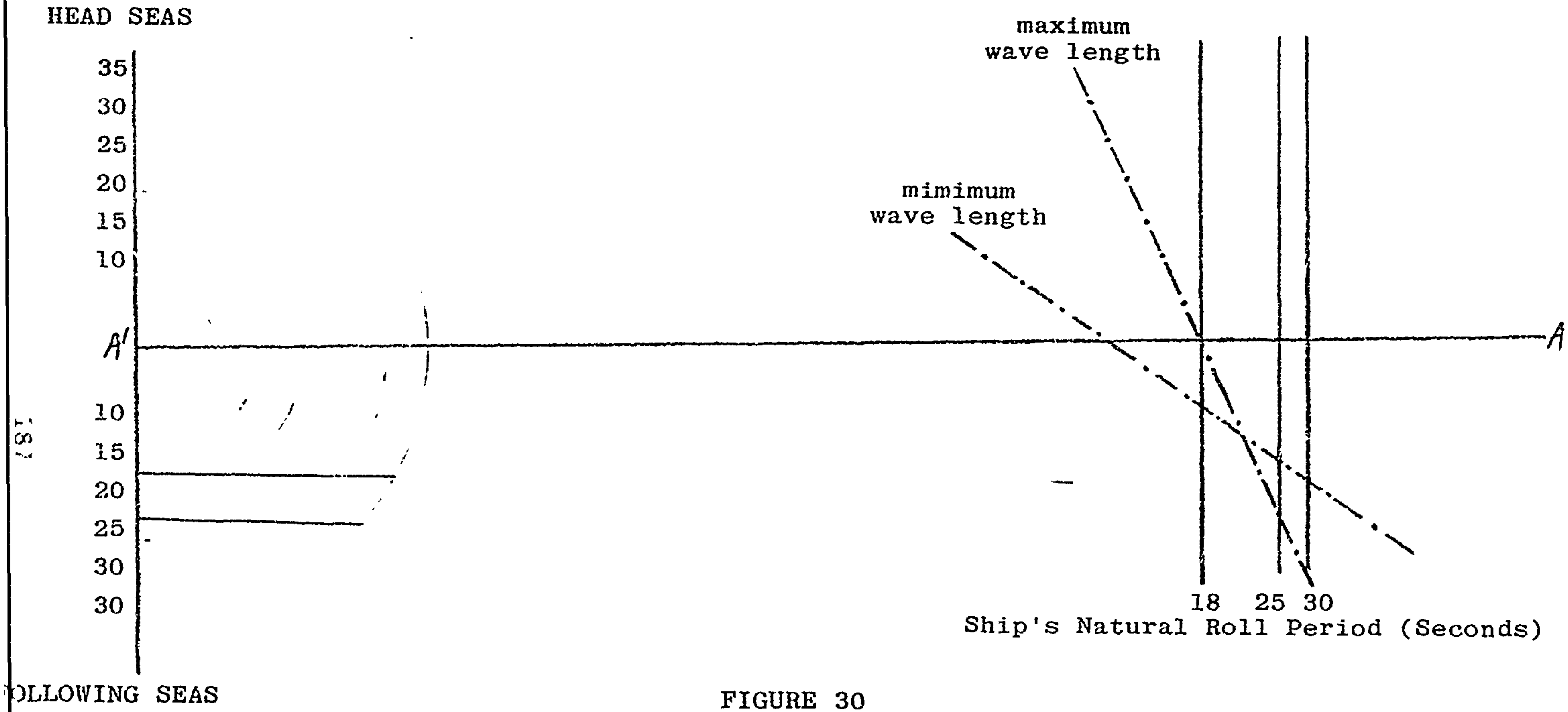


FIGURE 30

ZONES OF PROBABLE HEAVY ROLLING
Class Vessels Roll Periods = 18 seconds (ballast)
= 25 seconds (loaded, high GM)
= 30 seconds (loaded, small GM)

Ships' Service Area = Maximum wave length = 800'
= Minimum wave length = 200'

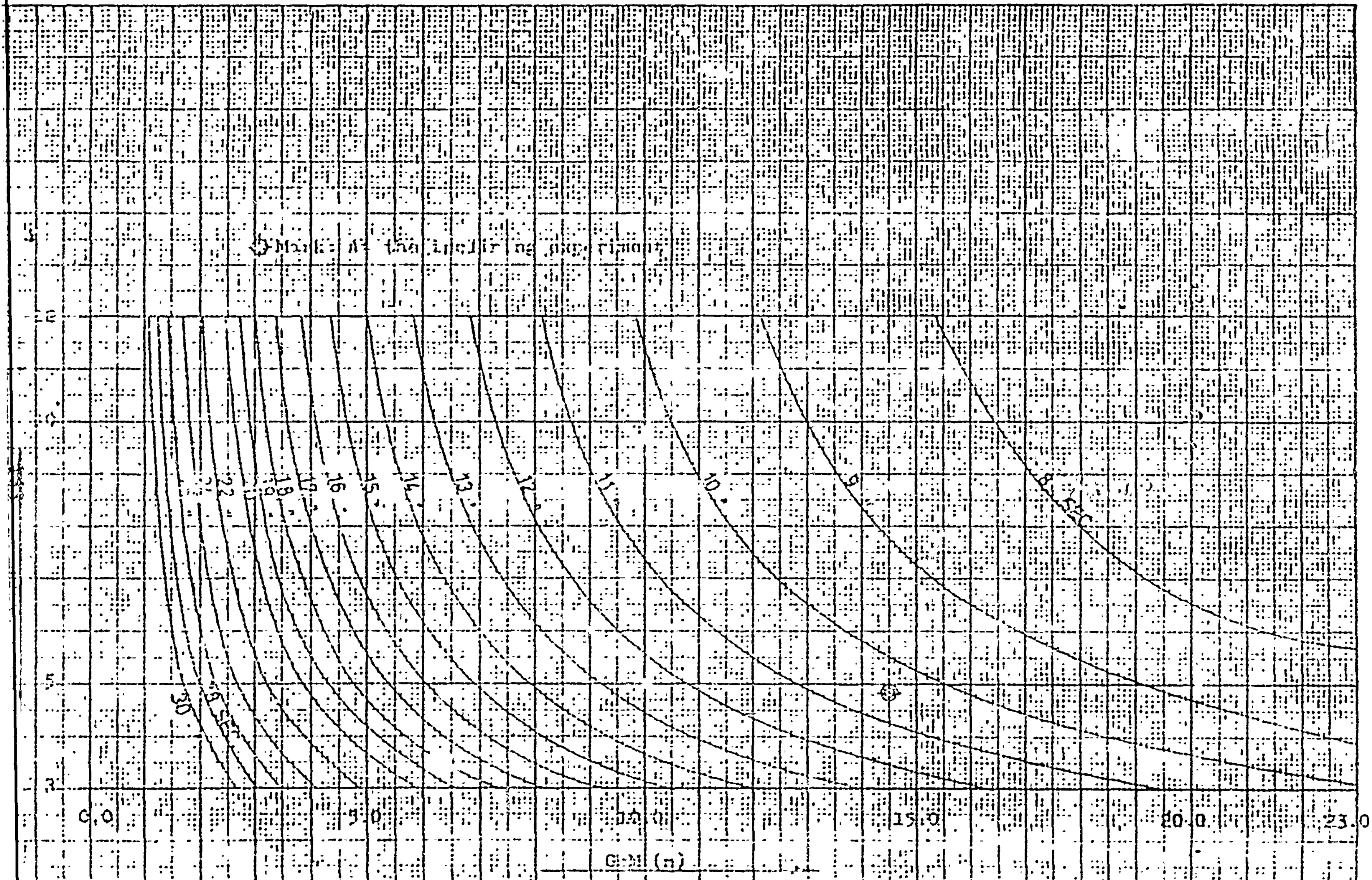


FIGURE 31 — TYPICAL GRAPH OF GM VS NATURAL ROLLING PERIOD

'confused sea', when it is properly explained and drawn up, it adds substantially to the operational information available.

Contrast this with Figure 31, the commonly-found presentation. The latter is explicit enough but lacks the operational guidance, e.g. does not specify zones of probable heavy rolling or suggest optimal changes in quantity and/or disposition of ballast

6.3.3 Cargo Space and Capacity Data

An overwhelming majority of masters and mates are critical of the completeness and accuracy of this component, and particularly of the divergence between ship and shore figures, some of which can be attributed to use of different tabulations of cargo spaces and capacities. The cargo spaces and capacities components should be improved and used by ship and terminal staff. A pocket size, comprehensive "ship's loading characteristics/ cargo space and capacity guide" should be developed, and its cargo space and capacity tabulation reproduced in the T&S booklet.

The cargo space and capacity table must be complete - every space identified, located, and entered with its grain and bale cubics (where applicable) and centers of gravity. This table should be supported with plans, profile, elevation, and sectional views of the ship indicating how these compartments are configured.

6.3.4 Consolidated Tankage Table

The same considerations of completeness, accuracy, and ship/shore uniformity which govern an optimal presentation of (dry) cargo space and capacity data apply to tanker cargo spaces and all vessels' tankage.

Similar tanks must be grouped if all relevant data is to be presented on one page. Cargo, cargo/ballast, and ballast tanks are self-evident groupings, but the provision of specialized tanks (sewage, flume, etc.) and engineering considerations obviously govern the makeup of the fuel-miscellaneous categories. The latter will also reflect the operator's choice of a literal or "effective" lightship (see Section 6.3.12, Appendix A). Effective lightship may include the 98%/5° and full-slack-for-largest-pair corrections, at the cost of additional conservatism in the final GM, or the free surface effect for the actual fuel tank pair in use can be used.

The tank capacities and centers table in dry cargo vessel booklets can be combined with table of moments of free surface. See Table 52, a computer printout of tankage. This tabulation already incorporates the correction for 98%/5° heel and therefore only the 'full slack' correction appears.

All tanks whose contents can be manipulated to affect trim, GM, and heel should have three column entries giving their simultaneous effect on these quantities (see Table 53). These can be precise or gross, as dictated by the normal operating needs and stability aids on board. The tables of gain in GM and 100T trim tables are too simplistic in their approach.

Tanker cargo spaces, and deep ballast tanks on dry cargo vessels, require tabulation of VCG against volume and sounding (and/or ullage) for several trims. There should still be a note of their effect on trim and stability, and space should be left in the booklet for mates' observations concerning particular effects.

TABLE 52

CAPACITIES, CENTERS OF GRAVITY AND FREE SURFACE MOMENTS OF OIL AND WATER TANKS (container vessel)

WATER BALLAST TANKS

COMPARTMENT	LOCATION (FRAME NUMBER)	**CAPACITIES 100% FULL CUBIC METERS	100% FULL TONS AT SG=1.00	100% FULL TONS AT 1.025	*CENTERS OF GRAVITY VCG ABV BL METERS	LCG FWD AP METERS	FREE SURFACE AT S.G.=1.00 TONS-METERS
#3 LOWER WING P	94-131	453.66	453.66	465.00	4.75	140.26	150
#3 LOWER WING S	94 131	453.66	453.66	465.00	4.75	140.26	150
#4 LOWER WING P	168 186	640.00	640.00	656.00	4.59	111.78	283
#4 LOWER WING S	168-186	640.00	640.00	656.00	4.59	111.78	283
LOWER PEAK TANK	282-300	350.15	350.15	358.90	3.41	219.56	129
UPPER PEAK TANK	282-300	363.61	363.61	372.70	14.05	217.94	258
#2 DOUBLE BOTTOM P	205-242	200.88	200.88	205.90	1.03	167.25	314
#2 DOUBLE BOTTOM S	205-242	133.17	133.17	136.50	1.08	165.97	134
#3 DOUBLE BOTTOM P	168-207	410.05	410.05	420.30	1.01	139.82	2030
#3 DOUBLE BOTTOM S	168-207	346.34	346.34	355.00	1.02	139.62	1322
#4 DOUBLE BOTTOM P	131-170	550.83	550.83	564.60	.97	112.35	4000
#4 DOUBLE BOTTOM S	131-170	485.37	485.37	497.50	.97	112.29	2815
#5 DOUBLE BOTTOM P	94-133	479.32	479.32	491.30	.98	85.25	2974
#5 DOUBLE BOTTOM S	94-133	414.05	414.05	424.40	.99	85.39	2023
AFT PEAK TANK P	4- 25	352.88	352.88	361.70	9.94	9.64	586
AFT PEAK TANK S	4- 25	352.88	352.88	361.70	9.94	9.64	586
#1 LOWER DEEP C	261-275	250.73	250.73	257.00	4.20	201.58	143
#1 UPPER DEEP P	261-282	605.46	605.46	620.60	13.25	203.56	362
#1 UPPER DEEP S	261-282	605.46	605.46	620.60	13.25	203.56	362
#3 DEEP TANK P	43- 59	127.22	127.22	130.40	3.49	35.17	31
#3 DEEP TANK S	43- 59	127.22	127.22	130.40	3.49	35.17	31
#4 DEEP TANK P	25- 43	154.44	154.44	158.30	5.37	23.78	148
#4 DEEP TANK S	25- 43	154.44	154.44	158.30	5.37	23.78	148
#4 UPPER WING P	131-168	682.15	682.15	699.20	11.91	112.01	50
#4 UPPER WING S	131-168	682.15	682.15	699.20	11.91	112.01	50
	TOTAL	10016.1	10016.1	10266.5	6.23	125.14	19362

NOTE:

1. TO OBTAIN WEIGHT OF LIQUID CONTENTS OF ANY COMPARTMENT MULTIPLY 'TONS AT S.G.=1' BY THE ACTUAL SPECIFIC GRAVITY OF THE LIQUID
2. SEE SHEET   FOR NOTES ON THE USE OF FREE SURFACE MOMENTS

TABLE 52 (continued)

CAPACITIES, CENTERS OF GRAVITY AND FREE SURFACE MOMENTS OF OIL AND WATER TANKS (container vessel)

FUEL OIL TANKS

COMPARTMENT	LOCATION (FRAME NUMBER)	**CAPACITIES***************** 100% FULL CUBIC METERS	98% FULL CUBIC METERS	98% FULL TONS AT SG= .900	*CENTERS OF GRAVITY*** VCG ABV BL METERS	LCG FWD AP METERS	FREE SURFACE AT S.G.=1.00 TONS-METERS
#5 WING P	85- 94	1313.38	1287.11	1158.40	8.41	83.50	367
#5 WING S	85- 94	1313.38	1287.11	1158.40	8.41	83.50	367
#3 UPPER WING P	88- 94	281.18	275.56	248.00	12.26	132.93	22
#3 UPPER WING S	88- 94	281.18	275.56	248.00	12.26	132.93	22
SETTLER P	242-261	368.48	361.11	325.00	5.62	66.28	639
SETTLER S	242-261	368.48	361.11	325.00	5.62	66.28	639
DAYTANK P	205-242	260.77	255.56	230.00	7.22	66.90	128
DAYTANK S	205-242	260.77	255.56	230.00	7.22	66.90	128
#2 DEEP TANK P	168-205	342.29	335.41	301.90	4.17	189.70	133
#2 DEEP TANK S	168-205	336.28	329.56	296.60	4.19	189.30	133
#2 LOWER WING P	131-168	504.08	494.00	444.60	4.67	168.90	191
#2 LOWER WING S	131-168	504.08	494.00	444.60	4.67	168.90	191
	TOTAL	6134.4	6011.7	5410.5	7.24	110.31	2960

NOTE:
1. TO OBTAIN WEIGHT OF LIQUID CONTENTS OF ANY COMPARTMENT MULTIPLY 'TONS AT S.G.=1' BY THE ACTUAL SPECIFIC GRAVITY OF THE LIQUID
2. SEE SHEET FOR NOTES ON THE USE OF FREE SURFACE MOMENTS

TABLE 53 - INTENDED PURPOSE OF TANKS

	Bending Moment*	GM	Required GM	Trim
Fore Peak Upper	+ Large	+	- Small	+ Large
Fore Peak Lower	+ Large	+ Large	- Small	+ Large
#1 Lower Deep	+	+ Large	- Small	+
#2 Double Bottom	+ Small	+ Large	- Small	+ Small
#3 Double Bottom	Nil	+ Large	- Small	Nil
#4 Double Bottom	Nil	+ Large	- Small	Nil
#5 Double Bottom	+ Small	+ Large	- Small	- Small
#3 Upper Wing	- Very Large	Nil	- Large	Nil
#3 Deep	+ Small	+ Small	- Small	-
Aft Peak	+	+	- Small	- Large

Note: Vessel usually hogging + - tending to increase hog
- - tending to decrease hog

Free surface correction can be tabulated for such large tanks, and the transient effects of free surface obtained by dividing the correction by the filling rate. Although GM is not usually of concern during these operations (on tankers, not at all) it is necessary to tabulate free surface for tanks other than consumables to cover situations where tanks are partially filled - for trim purposes, to remain at a certain deadweight and draft or while maneuvering in sheltered waters, etc.

6.3.5 Combined Table of Hydrostatics, Deadweight, Required GM, and Buoyancy Moment

Deadweight, GM, and hydrostatic data can be readily tabulated against (LCF) draft. The combined tabulation of these quantities is most concise where there is a unique GM for each draft. Since no more than three required GM curves for one vessel were found, however, tabulation remains feasible and preferred. Tabulation of the differences between entries facilitates interpolation without unduly bulking the table. Table 54 shows such an extended hydrostatics table.

In the workshops, 92% favored tabular presentation of GM and hydrostatics. A follow-up question asked about a suitable interval for tabulation by draft: 88% approved 3". The intervals should, however, reflect due regard for draft ranges in which hydrostatic properties are changing rapidly with sinkage. The order of columns should reflect the sequence of calculation. The first four columns relate to weights and draft (LCF draft, displacement, deadweight, and tons per inch immersion). A footnote might be added to the table regarding fresh water corrections. Columns 5 and 6 on Table 54, the LCB and MTI, are required for the estimation of trim. The next columns, KM and required GM,

TABLE 54 COMBINED HYDROSTATICS AND REQUIRED GM TABULATION

LCF DRAFT	TONS DISPL.	DEAD-WEIGHT	TP1	LCB	MT-1"	KM	Req. GM	BUOYANCY MOMENT

are needed for stability calculations. Where several curves of required GM appear, the conditions under which each column applies must be noted. For vessels requiring a (single) amidships bending moment calculation, a final column of buoyancy moment is needed. A note offering guidance as to whether or not interpolation is required for the various columns might be included.

6.3.6 Reduced Scale Long Form with Instructions

The layout of the calculation supporting worksheets was perceived as critically important to speed and accuracy of trim and stability calculations by 98% of workshop participants, most of whom were dissatisfied with their booklet forms.

These are simply blanks corresponding to the specimen long and short forms. These forms urgently need improvement; one highly regarded improvement (88% in favor) was commercial production, using a grid designed to guide the eye, separate calculations, and prevent transcription errors. (The grid employed in the report of the inclining experiment incorporates such design features.) Commercially printed forms can be made up in pads for ease of use. Whatever size of format is necessary can be obtained inexpensively by this means, without a corresponding expense in preparation of an outsize T&S booklet. The forms should have all fixed quantities preprinted on them. This would include, for example, centers of gravity for dedicated locations of unitized cargo. Inapplicable columns should be blanked. Additional aide-memoires such as signs, plans, formulae, etc. can be added to such commercially printed forms without loss of clarity.

The worksheet specimens reproduced as Figures 32-35

FIGURE 32 - LOADING SUMMARY SHEET AND WORKSHEET

LOADING SUMMARY SHEET

ITEM	WEIGHT L-TONS	LCG FROM F.P. FT	LONG'T MOMENT FT-L.TONS	VCG ABOVE B.L. FT	VERTICAL MOMENT FT-TONS	TCG FROM C.L. FT	TRANSVERSE MOMENT FT-L.TONS	FREE SURFACE FT-L.TONS
Lightship	24707.5	474.10		44.40		0.09		
Crew/Stores								
Cargo Oil								
Ballast								
Fuel/Diesel								
Lube Oil								
Fresh/Potable Water								
Miscellaneous								
TOTAL								

TRIM AND STABILITY CALCULATIONS

Condition: ____________

From Table of Hydrostatic Properties:

Displacement = tons

Draft at LCF = ft

LCB (graph reading) = ______ + 432' = LCB = ft

KM_t (graph reading) =

LCF =

MT1 =

TP1 = ft

Stability Calculations:

VCG = VCG above baseline = ft

Free Surface Correction = Free Surface Moment/Displacement

Free Surface Correction = ft

Available GM:

GM = (KM)-(VCG)-(Free Surface Correction)

GM = ft

Required GM = ft (see Curve page 21)

Trim Calculations: (-Fwd/Aft)

LCG = Ft

Trim = (LCG-LCB) x (Displacement)/(12x(MT1))

= Ft

List Calculations: (+ Port/- Stbd)(Acc. to 7 Deg)

TCG = Ft

List = (TCG) x (57.3)/(GM)

=

Draft Calculations:

Draft At FP = (LCF Draft)-(Trim x LCF)/(LBP)

= Ft

Draft at AP = (Draft at FP) + Trim

= Ft

Draft at Fwd Draft Mark = (Draft at FP) + (Trim/LBP)x (Dist to Fwd Draft Mark)

= Ft

Draft at Aft Draft Mark = (Draft at FP) + (Trim/LBP)x (Dist to Aft Draft Mark)

= Ft

FIGURE 33 CARGO/BALLAST TANK SUMMARY

ITEM	WEIGHT L.TONS	LCG FROM F.P. FT	LONG'L MOMENT FT-L.TONS	VCG ABOVE B.L. FT	VERTICAL MOMENT FT-TONS	TCG FROM C.L. FT	TRANSV. MOMENT FT-L.TONS	FREE SURFACE FT-L.TONS
CREW AND STORES								
Crew and Effects		751.25		75.0		0		
Stores and Consumables		751.25		75.0		0		
TOTAL		751.25		75.0		0		
CARGO OIL TANKS (Density = cu ft/LT)								
1 P Cargo Tank		122.27				55.23		
1 S Cargo Tank		122.27				-55.23		
1 C Cargo Tank		113.55				0		
2 C Cargo Tank		219.50				0		
3 P Cargo Tank		354.17				60.70		
3 S Cargo Tank		354.17				-60.70		
3 C Cargo Tank		354.17				0		
4 C Cargo Tank		488.83				0		
5 P Cargo Tank		604.65				59.81		
5 S Cargo Tank		604.65				-59.81		
5 C Cargo Tank		623.44				0		
Port Slop Tank		700.27				56.28		
Stbd Slop Tank		700.27				-56.28		
TOTAL								
FUEL OIL (Density = cu ft/LT)								
Port Fuel Oil Tank		766.68				50.76		
Stbd Fuel Oil Tank		766.68				-50.76		
Low Sulfur Fuel Tank		823.73				-43.46		
DIESEL OIL (Density = cu ft/LT)								
Diesel Oil Storage		823.72				40.46		
TOTAL								
LUBE OIL (Density = cu ft/LT)								
Fwd L.O. Storage Tank		765.00				-30.75		
Aft L.O. Storage Tank		770.00				-30.75		
L.O. Settling Tank		758.75				-30.25		
L.O. Gravity Tank		818.50				.50		
TOTAL								
FRESH & POTABLE WATER								
Inboard Freshwater Tank		830.92				6.62		
Outboard Freshwater Tank		830.00				25.00		
Inboard Pot. Water Tank		831.81				-12.63		
Outboard Pot. Water Tank		830.00				-25.00		
TOTAL								
MISCELLANEOUS								
Engine Room Holding Tank		0.92				-19.26		
Sludge Tank		814.80				7.17		
Sewage		752.50				-29.16		
TOTAL								

FIGURE 34

CARGO/BALLAST TANK SUMMARY

ITEM	WEIGHT L.TONS	LCG FROM F.P. FT	LONG'L MOMENT FT-L.TONS	VCG ABOVE B.L. FT	VERTICAL MOMENT FT-TONS	TCG FROM C.L. FT	TRANSV. MOMENT FT-L.TONS	FREE SURFACE FT-L.TONS
CREW AND STORES								
Crew and Effects		751.25		75.0		0		
Stores/Consumables		751.25		75.0		0		
TOTAL		751.25		75.0		0		
CARGO OIL TANKS (Density = 35.0 cu ft/LT)								
#3 C Cargo Oil Tank in Gale Ballast		354.17				0		
Forepeak Ballast Tank		34.17				0		
#2 P Ballast Tank		219.78				60.33		
#2 S Ballast Tank		219.78				-60.33		
#4 P Ballast Tank		488.83				60.52		
#4 S Ballast Tank		488.83				-60.52		
E/R Saddle Tank		733.36				0		
E R Double Bottom		778.52				1.58		
Afterpeak Ballast Tank		850.91				0		
TOTAL								
FUEL OIL (Density = cu ft/LT)								
Port Fuel Oil Tank		766.68				50.76		
Stbd Fuel Oil Tank		766.68				-50.76		
Low Sulfur Fuel Tank		823.72				-43.46		
DIESEL OIL (Density = cu ft/LT)								
Diesel Oil Storage		823.73				40.46		
TOTAL								
LUBE OIL (Density = cu ft/LT)								
Fwd. L.O. Storage Tank		765.00				-30.75		
Aft. L.O. Storage Tank		770.00				-30.75		
L.O. Settling Tank		758.75				-30.25		
L.O. Gravity Tank		818.50				.50		
TOTAL								
FRESH & POTABLE WATER (Density = cu ft/LT)								
Inboard Feedwater Tank		830.92				6.62		
Outboard Feedwater Tank		830.00				25.00		
Inboard Potable Wtr. Tank		831.81				-12.63		
Outboard Potable Wtr. Tank		830.00				-25.00		
TOTAL								
MISCELLANEOUS								
Engine Room Holding Tank		740.92				-19.26		
Sludge Tank		814.80				7.17		
Sewage		752.50				-29.16		
TOTAL								

FIGURE 35

LOAD CHANGE SUMMARY FORM

PORT ____________ DATE ________

	DEADWEIGHT (L.T.)	± AFT/FWD OF ⊗ LCG (FT)	LM (FT-TONS)	(ABOVE BL.) VCG FT	VM FT-TNS	KEEL DRAFTS FWD (FT)	AFT (FT)	+ BY STERN / − BY BOW TRIM (FT)
INITIAL CONDITION								
CHANGE(S) (+/−)								
NET CHANGE								
FINAL CONDITION								

VM_{MAX} =

preprint fixed quantities and set off totals, easing transcription to the loading summary sheet (which is identically laid out). The summary sheet and calculation record appear together. The latter records all the hydrostatic data upon which the calculation is based, speeding up any necessary checking.

Small changes to the loading condition are made when trim, draft, stability, or strength prove unsatisfactory, or when new external inputs are received (e.g. a change in cargo availability). While trim tables and tables of change in GM address this problem, in general, the iterative nature of load planning is not adequately recognized in existing trim and stability booklets. To deal better with this problem, the "loading sheet" Figure 32 for small changes is suggested.

6.3.7 Graph of Maximum Allowable Virtual Vertical Moment of Deadweight

The optimized T&S booklet would allow quick determination of adequate transverse stability by tabulating or graphing the maximum allowable vertical moment of deadweight, the simplest (equivalent) representation of the stability criterion (GM), against readily ascertained conditions of draft/displacement.

In conjunction with terminal-provided summary cargo data, and a hand-held calculator, the task of evaluating transverse stability becomes relatively simple and quick. Graphs/tables of maximum allowable longitudinal and vertical centers of gravity or moments are presently being included in loading manuals (see example developed by Captain W.M. Waldo of SS Seattle, and ABS' curve of maximum VCG vs draft, pp. 102 and 104. In addition to simplifying the application of the GM criterion of transverse stability, these presentations

facilitate vessel participation in the prestowage of container and other unit load types of vessels. By specifying the limits within which the terminal can arrange cargo (as required by individual unit weights, deck/underdeck stow requirements, ship configuration, etc.), the ship minimizes the risk of operational delays occurring because the prestow is unacceptable or takes too much time to be evaluated by the chief officer.

The principle can be generalized to longitudinal and transverse moments (e.g. Van Der Ham presentation of trimming moments).

The vertical moments are referenced to the baseline of the ship. A correction for free surfaces must be added. The horizontal axis of the graph should be calibrated in tons of deadweight. Where more than one curve must appear, a table setting out the conditions under which each curve may be used should appear on the same page as in Figure 36. Any additional information, such as a line corresponding to the load line deadweight, may be incorporated.

6.3.8 Van Der Ham Diagram

This presentation (see Figure 37; see also p. 90) related the deadweight and longitudinal moment of the vessel or deadweight to its drafts and/or trim. The recommended format has longitudinal moment of deadweight tonnage on the vertical. Aids to orientation may be included, such as load line, deadweight, and an amidships mark on the scale of moments. Diagonal curves of forward and after drafts cross the interior of the graph. Thus, once the loads and longitudinal moments of loads are summed, this graph can be entered directly and the drafts read off.

FIGURE 36

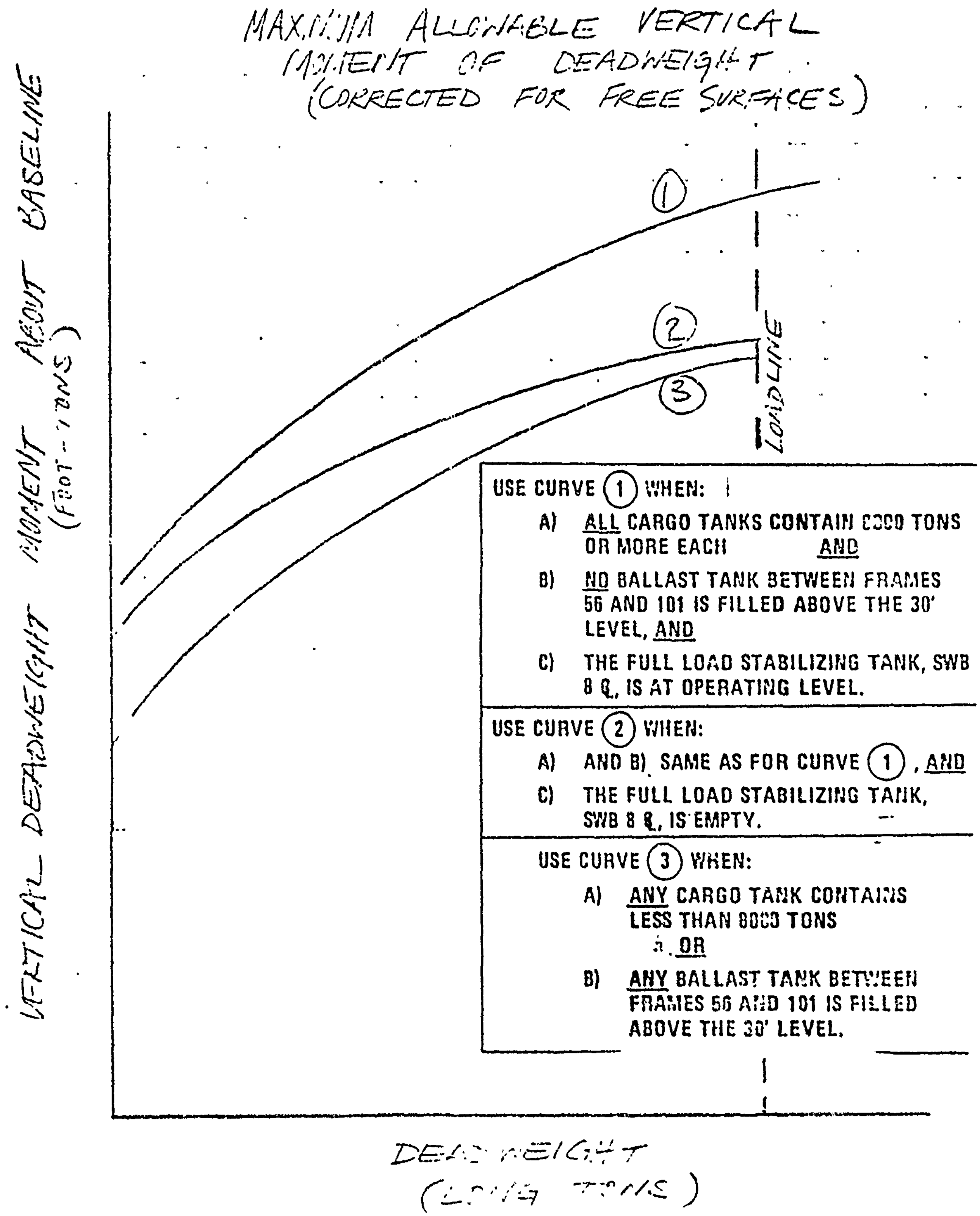
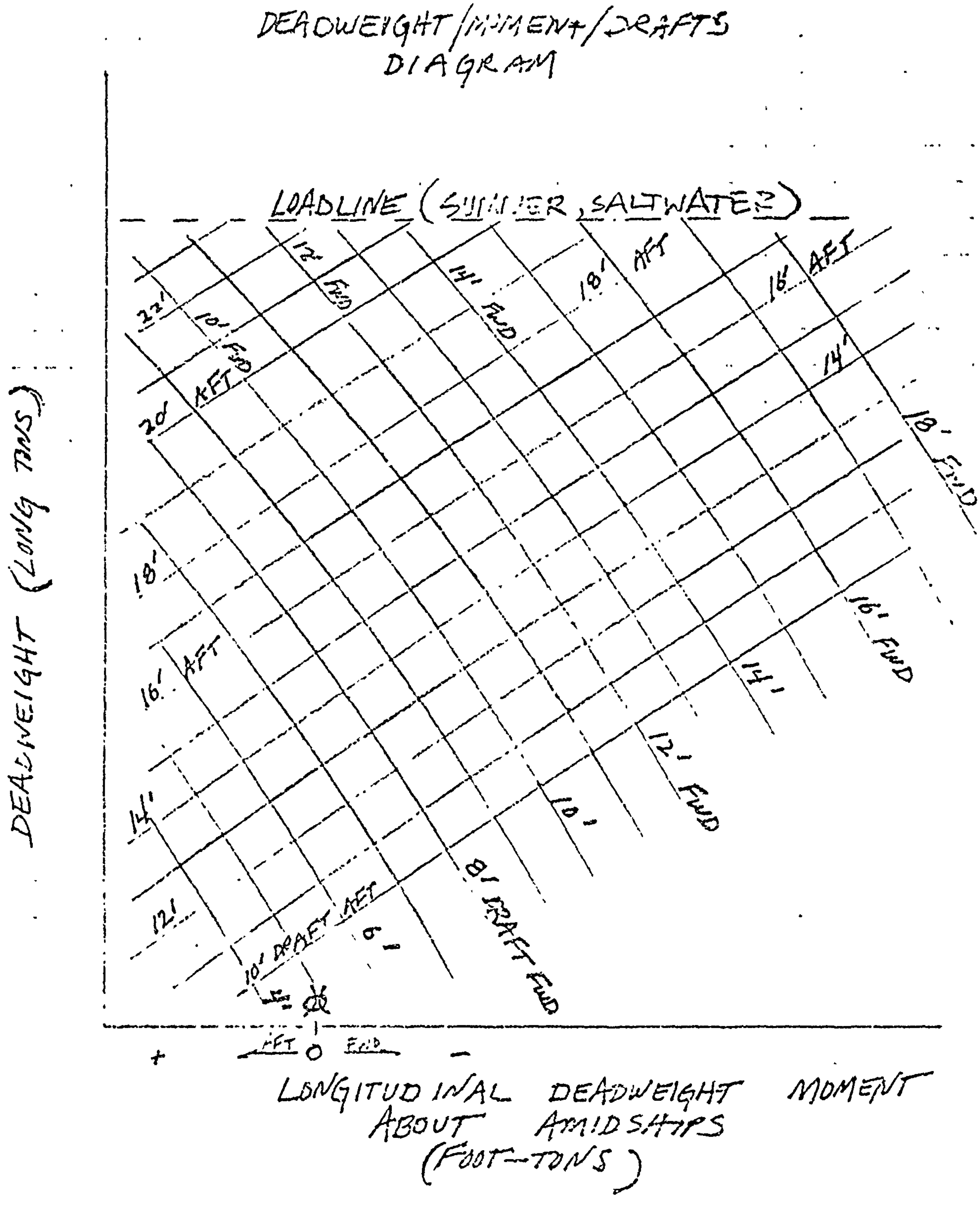

MAXIMUM ALLOWABLE VERTICAL
MOMENT OF DEADWEIGHT
(CORRECTED FOR FREE SURFACES)
VERTICAL DEADWEIGHT MOMENT ABOUT BASELINE
(FOOT-TONS)
1
2
3
LOAD LINE
USE CURVE 1 WHEN:
A) ALL CARGO TANKS CONTAIN 8000 TONS OR MORE EACH AND
B) NO BALLAST TANK BETWEEN FRAMES 56 AND 101 IS FILLED ABOVE THE 30' LEVEL, AND
C) THE FULL LOAD STABILIZING TANK, SWB 8 ℄, IS AT OPERATING LEVEL.
USE CURVE 2 WHEN:
A) AND B) SAME AS FOR CURVE 1, AND
C) THE FULL LOAD STABILIZING TANK, SWB 8 ℄, IS EMPTY.
USE CURVE 3 WHEN:
A) ANY CARGO TANK CONTAINS LESS THAN 8000 TONS
OR
B) ANY BALLAST TANK BETWEEN FRAMES 56 AND 101 IS FILLED ABOVE THE 30' LEVEL.
DEADWEIGHT
(LONG TONS)

FIGURE 37


DEADWEIGHT/MOMENT/DRAFTS
DIAGRAM
LOADLINE (SUMMER, SALTWATER)
DEADWEIGHT (LONG TONS)
22'
20' AFT
18'
16' AFT
14'
12'
10' DRAFT AFT
10' FWD
12' FWD
14' FWD
18' AFT
16' AFT
14'
18' FWD
16' FWD
14'
12' FWD
10'
8' DRAFT FWD
6'
AFT
O
FWD
+
-
LONGITUDINAL DEADWEIGHT MOMENT
ABOUT AMIDSHIPS
(FOOT-TONS)

6.3.9 Draft Particulars

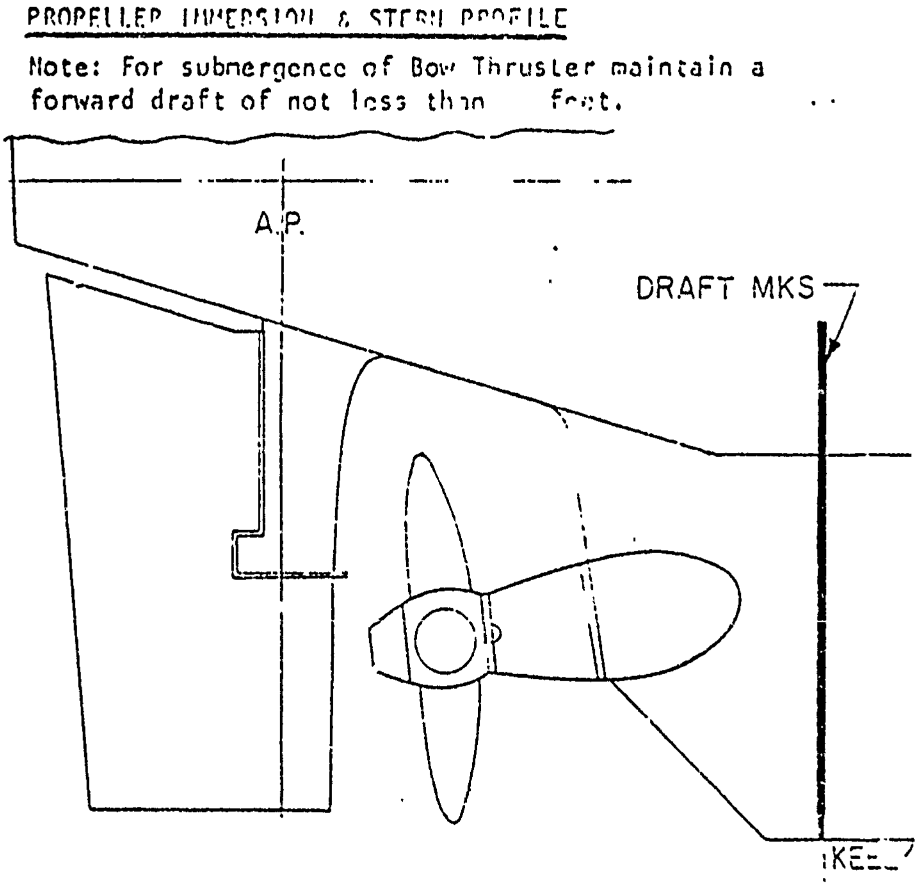
Nearly all methods of trim (draft) calculation result in drafts at the forward and after perpendiculars. As it usually is infeasible to weld draft marks to the hull precisely at the forward and after perpendiculars, there is no direct way to verify the draft calculation, and it is necessary to apply a correction to the calculated drafts at the perpendiculars to obtain measurable drafts at the marks.

For modern hull forms, it sometimes is extremely difficult for the naval architect to find a satisfactory place for the draft marks. This is generally due to the shape of the hull, which can create shadows, making the marks virtually invisible, or occasionally can have so little slope that the numerals (which must be 6" high in projection) turn out to be physically four feet high on the hull.

As a result, the corrections to obtain drafts at the marks can be quite large (up to 8" for the stern marks). They are never the same except for sister ships. The proper application of this correction is important, as calculated drafts which disagree with measured drafts cast doubt on the accuracy of the entire trim and stability book.

The presentation of the position of draft marks is frequently very poor in trim and stability books. The exact method to calculate the drafts at the marks from the drafts at F.P. and A.P. is not always made clear. The optimum trim and stability book will have an understandable treatment of this, in fact, simple problem.

Figure 38 shows a very clear description of the after hull geometry of a U.S. tanker. (In this case, the forward draft marks are at the forward perpendicular.) The simple formulas to calculate the propeller immersion



1. Draft to immerse propeller tip = (diameter of propeller + clearance)*
2. Draft at after mark = diameter of propeller - trim/20

* Fixed figure should be specified in an actual booklet

FIGURE 38

and after draft should appear. This level of after detail should be exhibited on a profile (Figure 39) showing the overall marks position. In the case of the European vessel in Figure 39, no draft correction was required until the after draft was less than 10 feet, which would only occur when the ship was being drydocked. As it is possible that these lower marks will at some time be necessary for a specific, probably critical calculation, an improvement of this treatment would give also the position of the lower after draft marks. See also page 209.

6.3.10 Cross Curves of Stability and Instructions for Plotting Statical Stability Curves

Cross curves of stability, which are generated in the design process, could be inexpensively provided to the ship. It would give the operators knowledge of dynamic stability, which the GM criterion does not. They should be calculated at intervals of heel not exceeding 10° (up to 50° heel) and as appropriate at larger angles of heel. The angle of downflood immersion should be shown, although considerable reserve stability may be embodied in the deck-houses. A calculation form for the curve of statical stability should be provided, preprinted with the appropriate angles and sines. The instructions for plotting should reflect the fact that the significance of the curve of statical stability is presently unfamiliar to many serving officers. It is necessary to control rolling, particularly in quartering seas, by changing speed and heading as necessary, in order to keep the vessel within its range of stability. Residual stability fluctuates with the wave configuration, which changes the vessel's underwater geometry.

Table 55 and Figure 41, taken from a U.S. flag

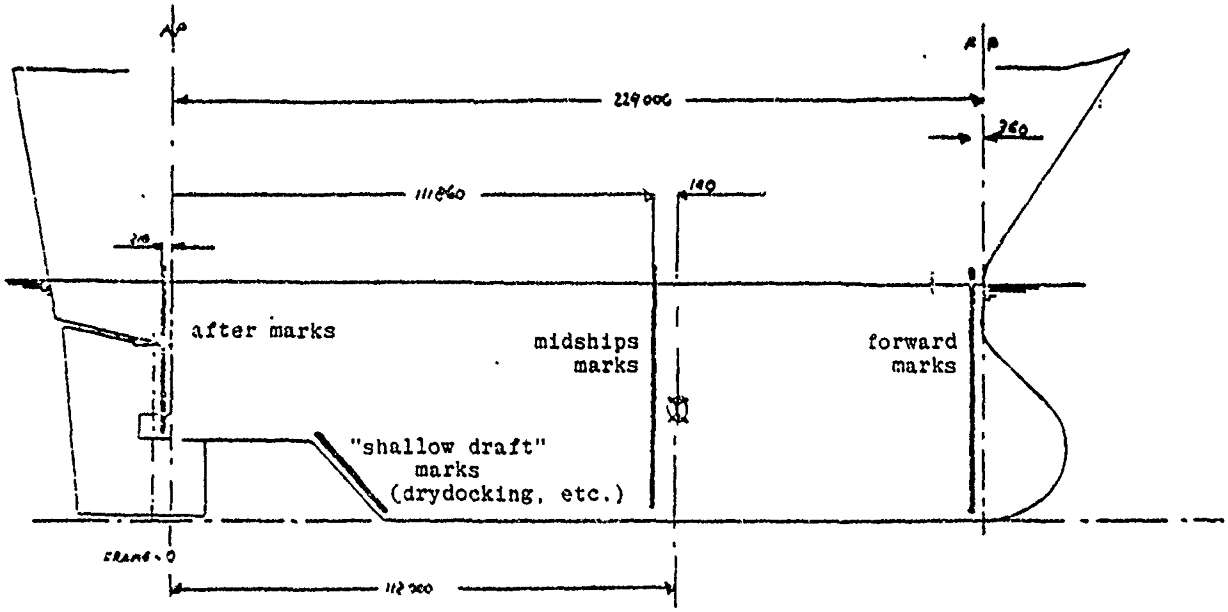


FIGURE 39: LONGITUDINAL PROFILE OF VESSEL SHOWING
DRAFT MARKS LOCATIONS

NB Note distances in cms

FIGURE 40

Increase in Draft Versus Heel Angle

Formula: $\Delta T = 1/2 \times B \times \sin\theta$

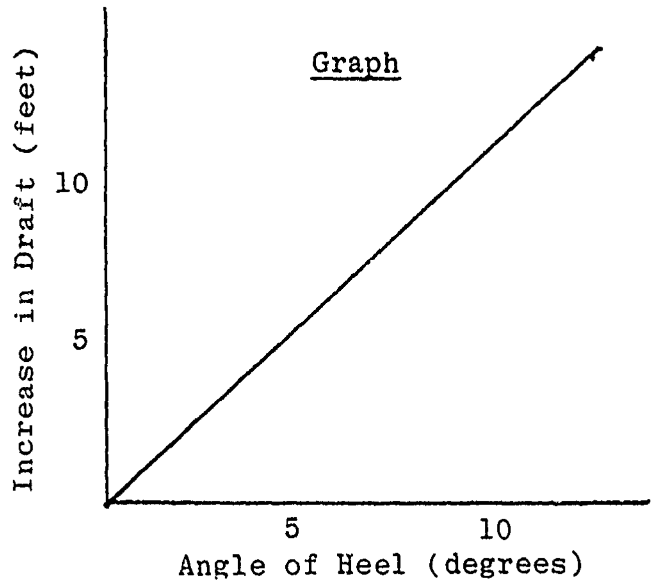
ΔT = increase in draft (feet)

B = beam of vessel (feet) = 100

θ = angle of heel (degrees)

Table

θ (degrees)	ΔT (feet)
0	0
1	.87
2	1.74
3	2.62
4	3.49
5	4.36
6	5.23
7	6.09
8	6.96
9	7.82
10	8.68



It would be appropriate, depending on the type of vessel, to include with the draft particulars a tabulation of the increase in draft for varying degrees of list. Container and barge-carrying vessels sometimes leave a quay with small underkeel clearances, and adjust ballast while leaving harbor. Masters of these vessel types expressed a desire for such a tabulation.

TABLE 55.

34000 DWT : TANKER

To plot the statical stability curves, values for GZ at each angle of heel are obtained from the Cross Curves for the displacement under consideration. Since the Cross Curves have been prepared with the vertical center of gravity of the ship assumed at twenty (20'-0") above the baseline, the values of GZ must be corrected by the formula, Correction = (KG-20) sin θ.

$$\text{Corrected } GZ_\theta = GZ_\theta - (KG-20)\sin\theta$$

where, GZ_θ: Righting arm read from cross curves of stability for the angle of heel θ

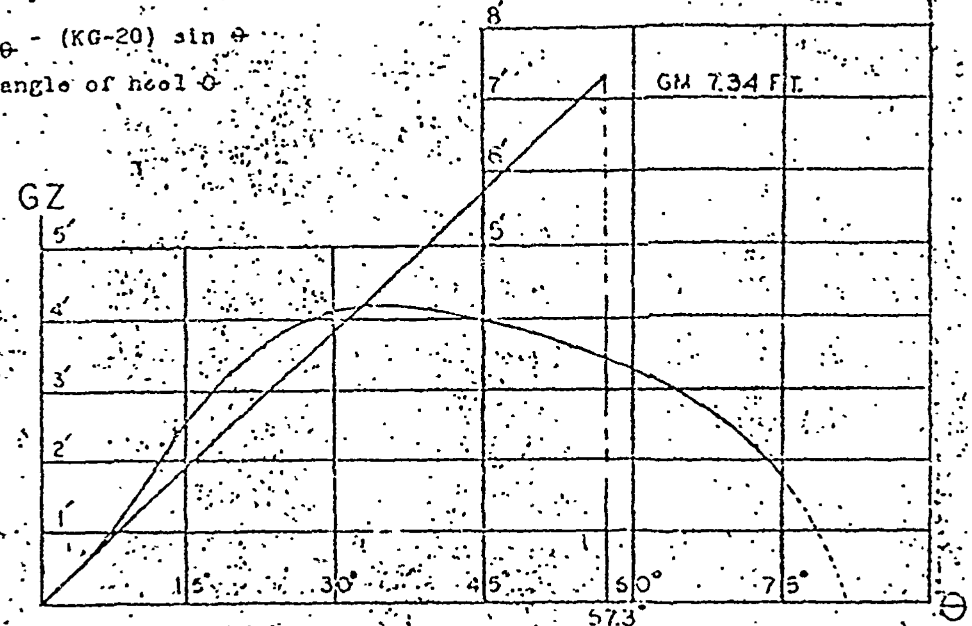
KG: True height of the vertical center of gravity

θ: Angle of heel

Calculation of actual GZ Curve for full load condition is as follows:

Δ = 45877 Tons

KG = 25.18 Ft.



Angle of heel	0°	15°	30°	45°	60°	75°
Sin. of Angle	0	0.259	0.500	0.707	0.866	0.966
(KG-20) sin θ	0	1.34	2.59	3.66	4.49	5.00
GZ From Cross Curves	0	4.15	6.99	7.50	7.98	6.98
GZ (CORR-KG)	0	2.81	4.40	4.24	3.49	1.98
GZ (CORR-F.S.)	0	2.53	4.11	3.98	3.27	1.78

The statical stability curve is obtained by plotting the corrected values for GZ vertically against θ plotted horizontally. Under normal conditions where the vessel has positive stability, the GZ curve will rise from zero, at zero angle of heel, reach a maximum value, and then decrease to zero. The angle at which the curve decreases to zero is the angle at which the vessel will theoretically capsize. This angle of heel is termed the range of stability.

It should be borne in mind that the statical stability curve is plotted from static conditions of heel. At sea, the angle to which the vessel rolls should be controlled to keep it well within the range of stability.

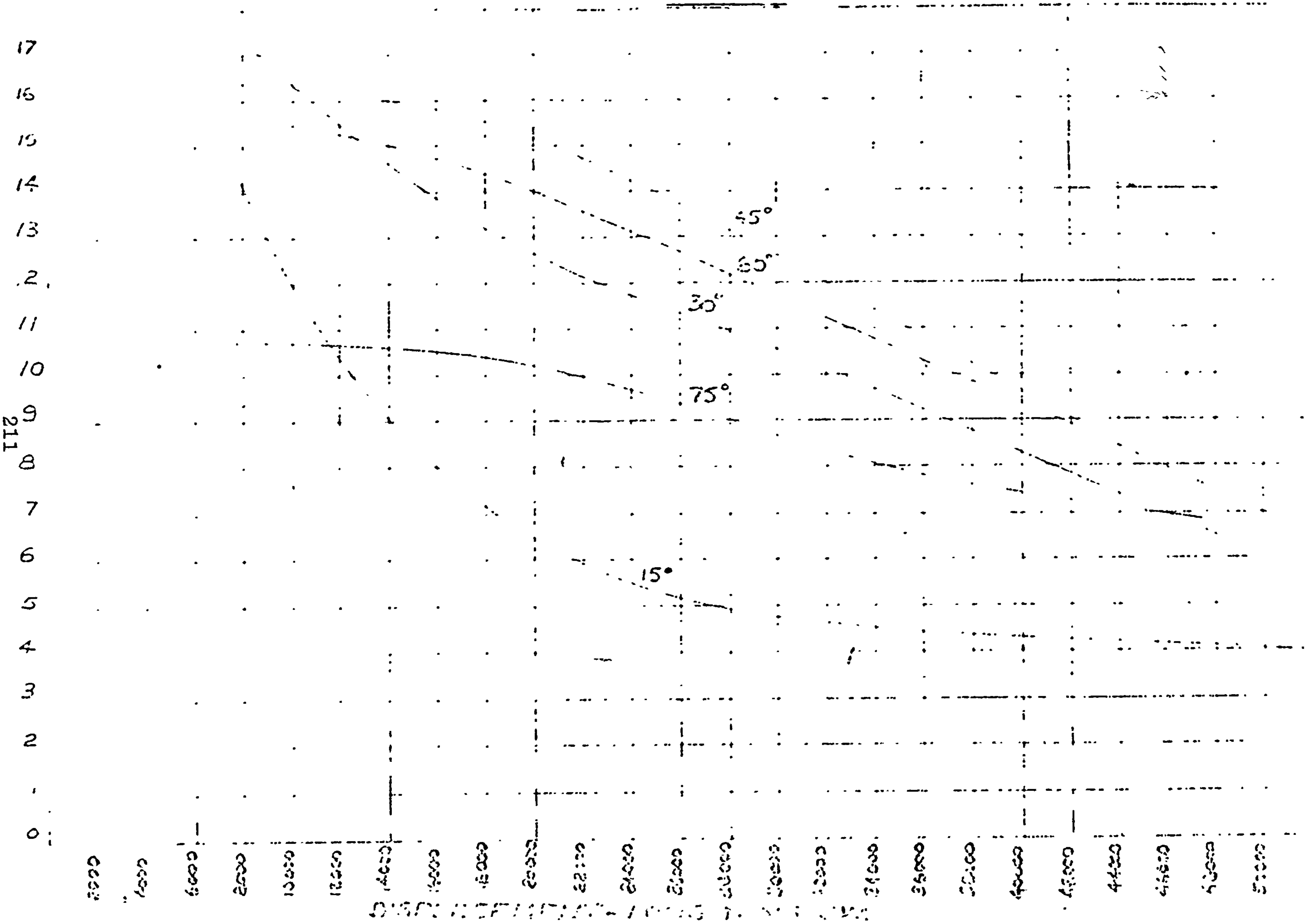
THE VERTICAL CENTER OF
ASSUMED 25-0' ABOVE
BASELINE

TANKER

CROSS CURVES OF STABILITY

SHIP ASSUMED WATERTIGHT
TO MAIN DECK FROM STEM
TO STERN

FIGURE 41



booklet, conform substantially to these requirements although the angle of down flood immersion is not shown. Figure 42 and Table 56 a and b were developed for a vessel subject to the IMCO criterion, and show how the latter subsumes operating instructions. More guidance than is given, in either the last sentence on p.210 - 'At sea, the angle to which the vessel rolls should be controlled to keep it well within the range of stability.' - or notes 2 and 3 of the IMCO example p 215 could be appropriately provided in the T&S booklet (and/or the Loading Manual).

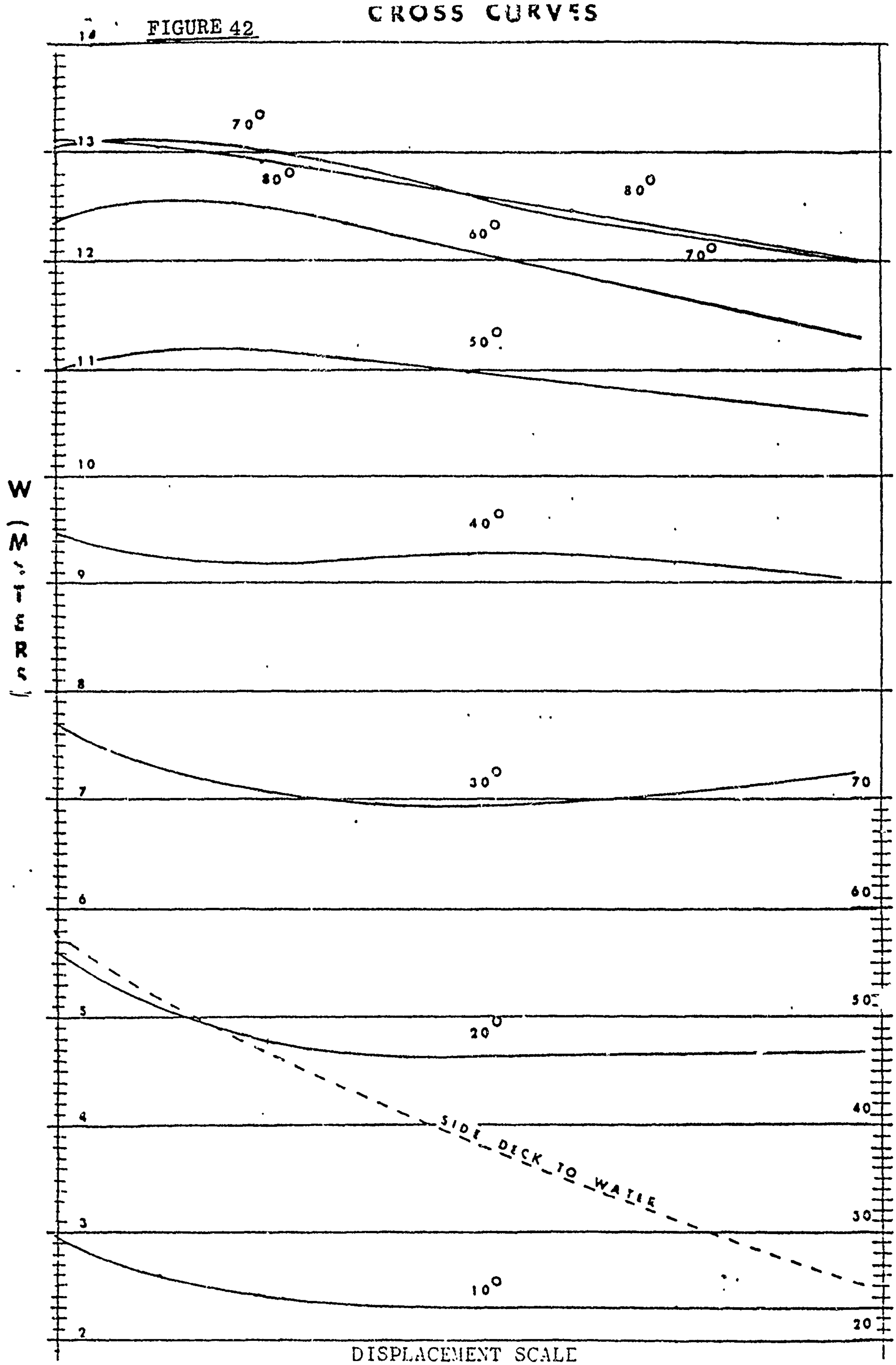
Note that the information suggested on areas of heavy rolling provides some assistance in controlling a vessel's roll.

6.3.11 Bending Stress Estimation

Several methods for calculating longitudinal stress are found in the various booklets. The primary reason for this diversity is that specific requirements for loading vessels are quite varied. Some vessels cannot be loaded so as to produce unsatisfactory stress levels. Others require only a midship bending moment calculation. Still others require shear and bending calculations at several locations along the length of the vessel.

A common approach is the stress numeral calculation, which is also called the "Mandelli method". This approach determines what percentage of the allowable stress level in the vessel has been reached, at one point - amidships. The procedure involves multiplying hold weights by "factors" and summing the products. The "factors" are derived from the LCG of the space and the allowable hog and sag bending moments. An analogous buoyancy numeral is read from a graph and added. An adjustment may be

FIGURE 42



CROSS CURVES
14
13
12
11
10
9
8
7
6
5
4
3
2
70°
80°
80°
60°
70°
50°
40°
30°
20°
10°
SIDE DECK TO WATER
W (METERS)
ANGLE (Ø)
70
60
50
40
30
20
DISPLACEMENT SCALE

EXAMPLE SHOWING USE OF CROSS CURVES (w)

The Purpose of The Cross Curves Is To Enable Statical Stability Curves To Be Drawn For The Ship In Any Sailing Condition, E. G. '

Assume The Displacement Of The Ship To Be 41 270,0 To, And The Vertical Center Of Gravity 12,24 m Above Base and the Free Surface Correction is 0.1 meters

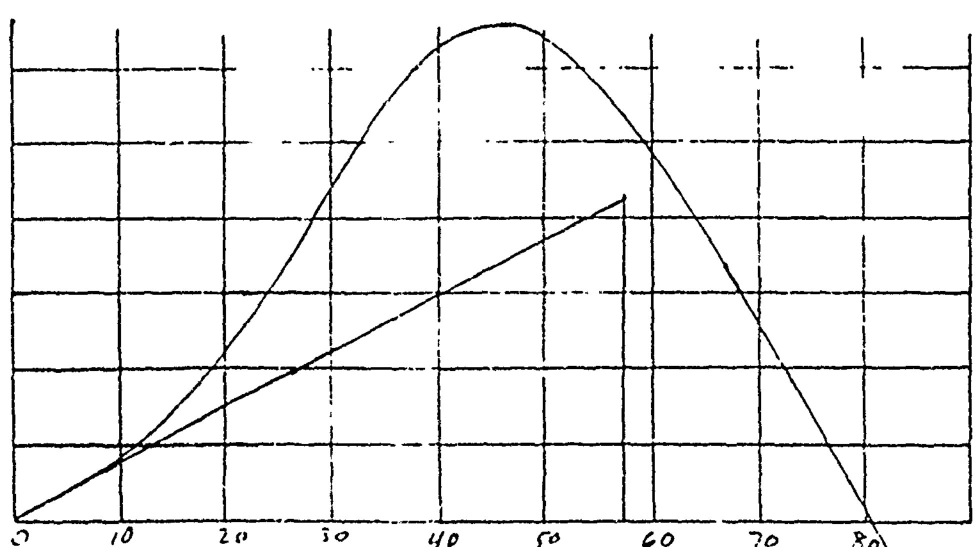
Then The Righting Lever $GZ = w - KG' \sin \varphi$,

Where w = Cross Curve Ordinate
KG' = Center of Gravity Above Base (corrected for Free Surface)
φ = Angle of Inclination
ΔD = Displacement

$\Delta D = 40\,263\ m^3$ $\quad KG' = 12,34\ m$

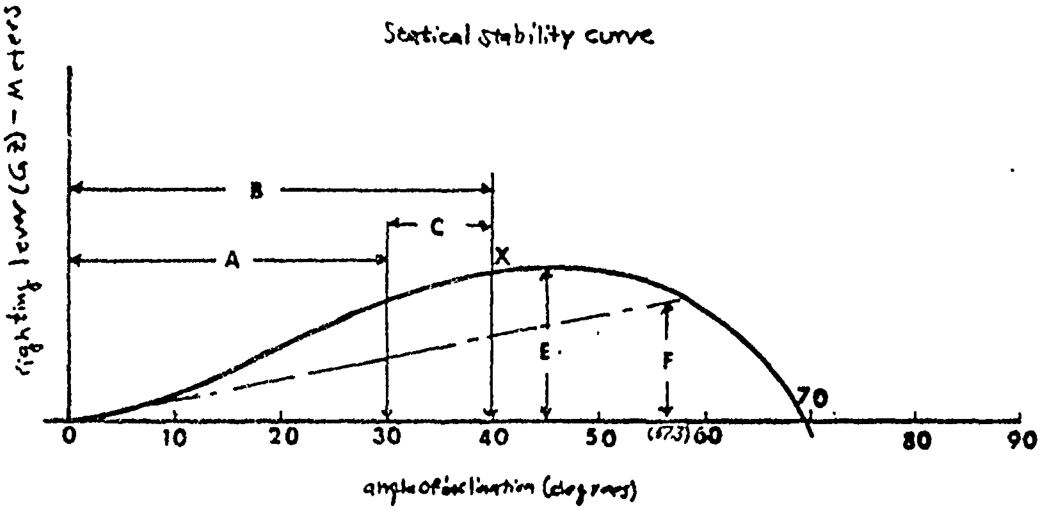
w At Δ 40263 m³	φ	$\sin\varphi$	$KG'\sin\varphi$	$GZ = w - KG'\sin\varphi$
2.30	10°	,1737	2,14	0,16
4,65	20°	,3420	4,22	0,43
7,05	30°	,5000	6,17	0,88
9,18	40°	,6428	7,93	1,25
10,73	50°	,7660	9,45	1.28
11,67	60°	,8660	10,69	0,98
12,14	70°	,9397	11,60	0,54
12,20	80°	,9848	12,15	0,05

Then By using The GZ Values in The Last column A Statical Stability Curve can Be Drawn FOR The Ship At The Displacement 41 270 to



Special Notes On Stability

1. As this ship is required to comply with Schedule 4, Part I para. 2 of the 1968 Load Line Rules it is most important to ensure that in any sailing condition the stability complies at least with the following minimum Criteria:



A – area under curve up to 30 degrees to be not less than 0.055 metre-radian

B – area under curve up to x degrees to be not less than 0.09 metre-radian

C – area between 30 degrees and x degrees to be not less than 0.03 metre-radian

X – 40 degrees or any lesser angle at which the lower edges of any openings in the hull, superstructure or deckhouse which lead below deck and cannot be closed weathertight would be immersed

E – maximum GZ to occur at angle not less than 30 degrees and to be at least .2 meters in height

F – initial GM Not to be less than 0.15 meters:

2. Ballast Note

In determining the sequence of tanks from which Fuel Oil is to be consumed and those into which water ballast is to be admitted during the voyage, it must be ensured that throughout these operations the stability will not, at any stage, fall below the afore mentioned criterion, due allowance being made for free surface effects

3. General Precautions Against Capsizing

Compliance with the Stability Criterion noticed above does not ensure immunity against capsizing regardless of the circumstances or absolve the Master from his responsibilities. Masters should therefore exercise prudence and good seamanship having regard to the season of the year, weather forecasts and navigational zone and should take the appropriate action as to speed and course warranted by the prevailing circumstances

incorporated in the factors to ensure that the products are all positive. A recommended format for a midship bending moment calculation is given in Figure 43. Instructions are included on the form. The lightship moment numerals can be read from the augmented hydrostatics table, Table 54.

The best means of satisfying the operational requirements for speed and accuracy in bending moment calculations is the use of electronic aids, especially when stresses at several stations are required. These must of necessity have clear instructions for use and an independent (manual) means of carrying out the calculations must be provided (the T&S booklet).

FIGURE 43

TABLE FOR DETERMINING BENDING MOMENT NUMERALS FROM LOAD DISTRIBUTION

CONDITION:

LINE NO.	ITEM		WEIGHT L.T./100 (A)	FACT. (B)	NUM. (C)
1	CARGO NO. 1			3.535	
2	CARGO NO. 2			3.133	
3	CARGO NO. 3			2.605	
4	CARGO NO. 4			2.237	
5	CARGO NO. 5			2.413	
6	CARGO NO. 6			2.094	
7	FWD DEEP TANK			3.369	
8	F.O. SETTLERS	P&S		3.190	
9	LOW SULFUR F.O.	P		3.249	
10	LUBE OIL			3.299	
11	DIESEL OIL	S		[illegible]	
12	NITROGEN			2.997	
13	POTABLE WATER	P		3.132	
14	DISTILLED WATER	S		3.192	
15	FOREPEAK			4.037	
16	WING NO. 1	P&S		3.549	
17	UPPER WING #2	P&S		3.129	
18	LOWER WING #2	P&S		3.109	
19	UPPER WING #3	P&S		2.601	
20	LOWER WING #3	P&S		2.507	
21	UPPER WING #4	P&S		2.222	
22	LOWER WING #4	P&S		2.209	
23	UPPER WING #5	P&S		2.429	
24	LOWER WING #5	P&S		2.429	
25	UPPER WING #6	P&S		2.393	
26	LOWER WING #6	P&S		2.909	
27	WING NO. 7	P&S		3.331	
28	DOUBLE BOTTOM			3.300	
29	AFT DEEP TANK			3.652	
30	AFTER PEAK			3.097	
31	STABILITY NO. 1			3.563	
32	STABILITY NO. 2			3.675	
33	CREW & STORES			3.365	
34	SUB-TOTALS (LINE 1 THRU 33)			—	
35	LIGHT SHIP		326.16	—	
36	TOTALS (LINE 34 + LINE 35)			—	
37	DOWT. BOAR. (3 x LINE 34 COL. A)		—	—	
38	BENDING MOMENT NUMERAL		—	—	

I - ENTER WEIGHT (LONG TONS DIVIDED BY 100) [illegible] VESSEL, ON THE APPLICABLE LINE IN COLUMN (A).

II - MULTIPLY EACH ENTRY IN COLUMN (A) BY THE FACTOR IN COLUMN (B) AND ENTER PRODUCT IN COLUMN (C).

III - ADD ENTRIES IN COLUMNS (A) AND (C) ON LINES 1 THRU 33 AND ENTER THE RESPECTIVE SUMS ON LINE 34.

IV - OBTAIN LIGHT SHIP NUMERAL FROM GRAPH AND ENTER ON LINE 35 COLUMN (C).

V - TRIPLE NUMBER ON LINE 34 COLUMN (A) AND ENTER PRODUCT ON LINE 37 COLUMN (C).

VI - ADD ENTRIES ON LINES 34 AND 35 IN COLUMN (A) AND ENTER ON LINE 36. THIS IS THE VESSEL'S DISPLACEMENT IN LONG TONS DIVIDED BY 100, AND SHOULD CHECK APPROXIMATELY WITH DISPLACEMENT AS OBSERVED FROM SHIP'S DRAFTS.

VII - ADD ENTRIES ON LINES 34 AND 35 IN COLUMN (C) AND ENTER SUM ON LINE 36. DEDUCT ENTRY ON LINE 37 FROM THAT ON LINE 36, AND ENTER DIFFERENCE ON LINE 38. A POSITIVE RESULT INDICATES HOGGING, A NEGATIVE RESULT, SAGGING.

Appendices A, B, and C.

The following pages are the suggested appendices to the recommended Trim and Stability Booklet. These pages are not required for normal operation of the vessel and therefore should occupy a subsidiary place in the booklet.

A. Vessel's Principal Characteristics and Effective Lightship Condition

NAME OF VESSEL: ______________________ BUILDER: ______________________

DATE OF KEEL LAYING: ______________________ YARD NO.: ______________________

Classification society and class: ______________________

Port of registry: ______________________

Principal dimensions:

LOA: ____________

Extreme Draft: ____________

Maximum Beam: ____________

Displ. and DWT @ Maximum Draft: ____________

Keel height of highest fixed structure (identify): ______ (even keel)

______ (x' trim)

The material in this booklet is drawn from:

capacity plan (diagram no.)

tank capacity curves (diagram no.)

hydrostatic curves (diagram no.)

damage stability curves (diagram no.)

longitudinal strength calculations (diagram no.)

Definition of Lightship

Lightship weight and centers determined from the inclining experiment: ____________

Lightship weight and centers used in this booklet: ______________________

The lightship used in the booklet includes an assumed average weight for the following:

crew effects ______________________

stores ______________________

retained sanitary wastes ______________________

unpumpable bilges ______________________

etc.

Permanent Ballast

A Table of Vessel's Principal Characteristics and Details of Effective Lightship Condition

Respondants wished to retain this feature, although it contributes nothing to the booklet's safety and guidance function. Accordingly, it is suggested that it be relegated to the rear of the booklet. The booklet's source and allied information should be explicitly noted for reference purposes.

B. Sample Loading Conditions

These are frequently by-passed in favor of records of actual cargo, because the sample conditions are boring to read, generally unrealistic, and not, in fact, very helpful in understanding the logic of the calculations.

It has been pointed out that these sample conditions are intended to serve as a verification for the classification societies, regulatory bodies, and buyer that the vessel can perform as specified. They are too much oriented to this verification function, and, even so, do not always accurately depict the operational capacity of the vessel. Once again the divergence in the users' and designers' aims and needs makes the output - the sample loading conditions - unrewarding for the designer to develop and useless for the officer to use in becoming aware of the operational capabilities of his vessel.

C. Damage Stability Information

Workshop participants were most familiar with the Sea Land damage stability book, written by Robert Macy. This was very favorably perceived. Overall, there was little familiarity with damage stability information and presentations. Floodable length curves, which *are* treated in texts, had not been seen or used by any serving mariner contacted during the study.

Several companies, notably tanker operators, were in the process of establishing headquarters casualty resource centers, provided with extensive computer resources. Concurrently, they were removing or downplaying damage stability information on vessels. Most companies providing information did so in the form of an unedited printout, which would be useful primarily to a naval architect. Damage control is one area in which instructions for the use of the materials provided are of overwhelming importance: there needs to be a clear sequence of instructions for evaluating emergencies in an appendix to the booklet. The following is suggested for its contents.

1. Source and summary of damage stability standards, e.g. vessel is MarAd two-compartment standard; must remain afloat and listed not more than 7° after the final stage of flooding of any two compartments.
2. Prioritized list of actions to take immediately - ascertain location and extent of damage, dump flumes, close particular valves and doors, etc. (list obviously dependent on vessel type and structure).
3. Possible short term options and guidance in choosing best course of action.

A minimally complex presentation of damage stability might describe the worst cases underlying the designers'

calculation or the required GM curve (if this is damage-determined). The site, development, and ultimate consequence of the penetration in light and load conditions should be simply described. The permeability assumptions should be explicit, e.g. is 'empty' literally empty? A tabulation of 'pattern' casualties may be feasible if the number of compartments is small.

If a specific booklet is to incorporate sufficient data to make actual damaged stability calculations, then hydrostatic data for damaged conditions, i.e. grossly trimmed and deeper draft, will have to be provided, together with capacity data for voids, engine room, and other uncalibrated spaces. Permeabilities must be realistic. The data and computation must be fully explained. It may be argued that it is more realistic to provide guidelines for a) abandoning ship or b) utilizing advice obtained over the radio telephone from head office naval architects and/or emergency response teams. The one extant form of abandonment diagnostic tool - the floodable length curves - is explained in some academy stability courses, but no examples were found in booklets. The concept was not understood - scarcely remembered, in fact - by serving ships' officers.

6.4 Computer Systems

The preceding recommendations have been developed bearing in mind the USCG requirements for a hard-copy T&S booklet, independent of electronic aids. However, among the respondants to this study, 60% or more of masters and mates rely on electronic aids, and at least 40% of operators are presently reviewing their attitudes toward marine automation. The project staff feels that shipboard computers are the best, most cost-effective solution to the problem of quick, accurate, complete stability information. This section is devoted to a review of in-house experience with computerized stability calculations and microprocessor performance, which will assist the Coast Guard to arrive at a realistic policy toward marine automation in the area of stability calculation.

Shipboard computers fall into two general categories - analog and digital. Analog computers perform integration particularly efficiently and work best where the most important variables are structured and can be expressed by equations (shear force and bending moment), and where few inputs are needed. Accordingly, they find their best applications in tanker loading. They do not calculate GM and drafts as accurately as digital equipment, which is better suited to arithmetic calculations. On large tankers, stability parameters are of smaller importance than the stress.

On other types of vessels, digital equipment is usually installed, primarily because it can easily accept the numerous complicated weights involved in modern cargo calculations. A secondary advantage of the digital equipment is that it is much cheaper. The advent of the inexpensive (digital) microprocesser computers in 1977, created a tremendous potential for the proper

computational solution to vessel loading problems.

In principle, the available microcomputers have the potential for calculating from first principles (formulae) all parameters associated with vessel loading, for checking input exhaustively for plausibility, and for ensuring that shore and ship's personnel operate from a common set of figures. They also have the ability to reduce the time required to calculate various conditions, this making it feasible for the mate to perform all the requisite calculations, even during short port calls, and to experiment with different ballast conditions.

Nearly all container operators have chosen to install digital computers onboard to allow accurate calculation of stress, trim, and stability. Usually this is done with a general purpose computer programmed by an engineer-programmer in the employ of the company. More recent efforts in this line have been to provide loading plans, manifests, etc. on floppy discs, eliminating paper as the primary medium (although hard-copy may be supplied too).

As these systems have diverse origins, there is no uniformity in their implementation. Nearly all accomplish the necessary tasks (Table 57), using a program flow resembling Figure 44.

Assuming the program to be properly debugged, the equipment has many advantages over hand calculations. First, all calculations are internally consistent. The accuracy of bending moment and stability calculation is at least partially verified if the calculated and actual draft marks agree. If the actual draft disagrees with the calculated draft, then most likely GM and bending moments are also wrong. No such verification occurs with manual calculations, where bending moment and trim and stability are usually calculated by independent

TABLE 57 FEATURES OF COMPUTER SYSTEM

Output

- Drafts forward and aft
- GM before and after free surface correction
- GM required according to U.S. Coast Guard
- statical stability curve according to IMCO rules
- still water bending moment
- required still water bending moment

  NOTE: Virtually impossible for any of the above to be incorrect if actual drafts of vessel agree with calculated

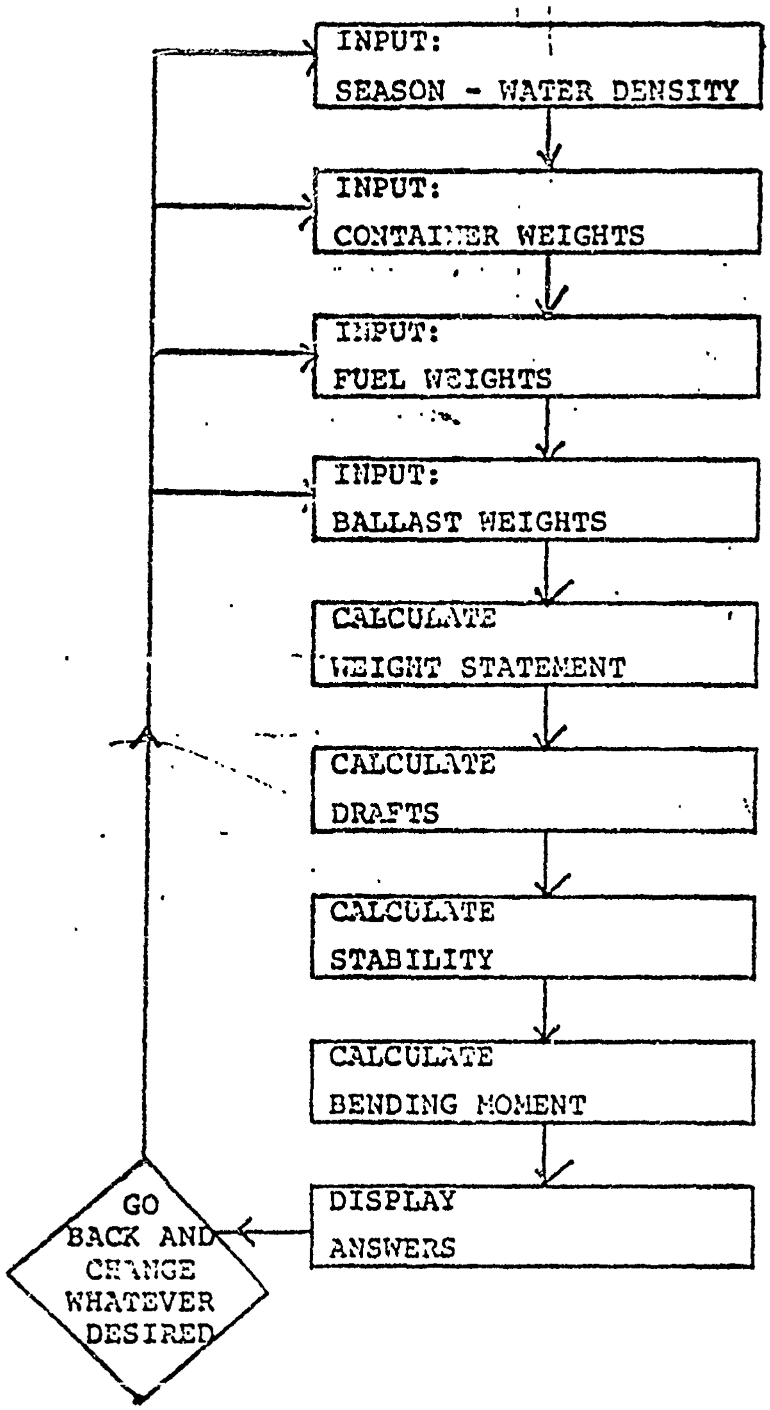
Input

- container weights by bay and tier
- fuel weights
- ballast weights
- water type (salt or fresh)
- season (for ice accretion allowance)

General Features

- error checking of container weights
- error checking of fuel and ballast weights
- clear correlation between Trim and Stability Book and computer
- elimination of arithmetic errors
- correct calculation of free surface deduction
- icing allowance correctly calculated
- no confusion concerning % consumables

FIGURE 44 - FLOW CHART OF COMPUTER PROGRAM



procedures.

The process surrounding the approval of such equipment and programs is curious. The basic position is that as long as the trim and stability book is aboard, such material is classed as "owner's supplemental information to the master" and need not be approved at all. This makes the installation of such equipment somewhat cheaper. However, the goal of the equipment is to supplant the trim and stability book, so that a more rational position is to require the programs to reproduce at least most of the conditions in the trim and stability book.

A second curious aspect of the situation is the condition for classification society approval, the first one being that ABS will not approve anything which is not part of the ship. Thus ABS gives certificates for anchor chain but not rope, for radars but not sextants. For the older analog computers the program was hardwired custom for each ship and the computer more or less physically attached to the ship. For these machines ABS certification was easy. The surveyor of the vessel during its construction verified that the computer worked and issued a certificate.

The modern minicomputer system uses removable discs or tapes which are not really part of the ship. The programs are easily changed. Thus, as recently experienced by the contractor, ABS feels that the actual computer is not under its jurisdiction, although it is willing to approve hard copy output of the program.

While this particular vessel was English flag, a similar situation was encountered with the trim and stability section of the program. The final result was that the program was not approved, although it could of course be used. Its output was made into a new trim and

stability book which was approved.

This approach, making the trim and stability book a hard copy of the output of the vessel's trim and stability program, seems to have much to recommend it. In any case, acceptance of microcomputers by the ship's crew is extremely good, even enthusiastic. Nearly all participants in our workshops who had experience with microcomputers preferred them to hand calculations.

Systems involving identical microcomputers ashore and aboard ship have tremendous potential for improving container ship stowage. They make the trim and stability data available to the stevedores, who use this information to solve problems with cargo, which the crew formerly had to solve with ballast.

The contractor has experience with two such systems, both very similar in philosophy. Each involved a microcomputer on each ship and one in the main offices in Europe and the United States. The first system, which E. G. Frankel Inc. installed, was largely responsible for the improvement in operations discussed in the introduction (see Figure 45).

The second system was implemented to deal with structural failures affecting about half of a major operator's fleet. The system was very successful in controlling the loading of vessels to minimize bending stress, and extended the life of the vessels by at least four years.

In closing, some discussion of the reliability of computers is necessary. The most unreliable element of such a shipyard computation system is the vessel's own electric power. Many problems could be circumvented by putting such equipment on the emergency board.

Table 58 gives the maintenance history of 8 microcomputers used aboard ships in trim and stability

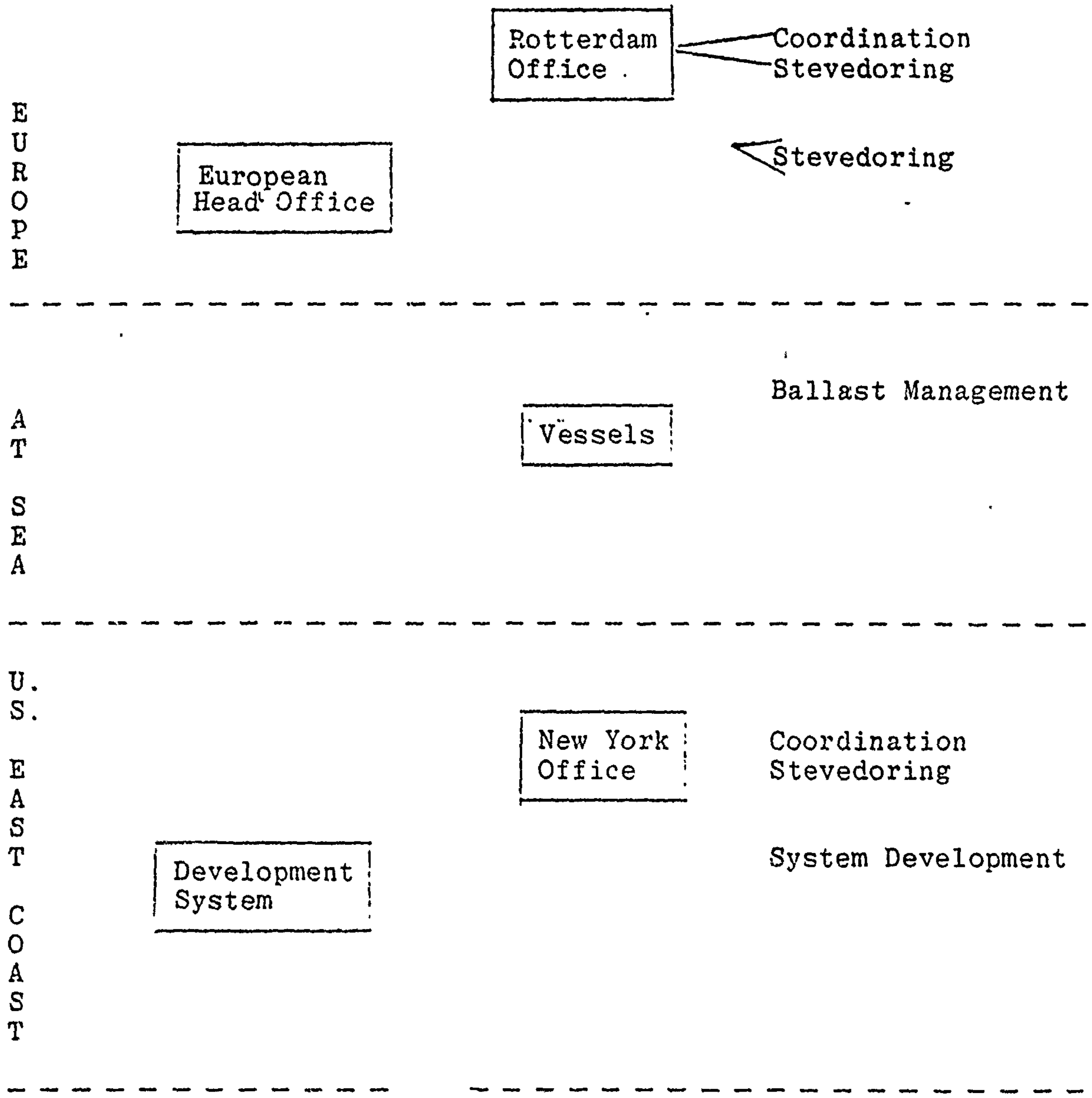


FIGURE 45 DEPLOYMENT OF COMPUTER SYSTEM

TABLE 58 SERVICE HISTORY - 10 MICRO COMPUTER INSTALLATION

SOURCES OF FAILURES

- Static Electricity (Seldom problem on ship)
- Mechanical Problems
  - Keyboards
  - Printing Mechanisms
- Removing Components without power off
- Failure to run equipment ashore prior to installation on ship
- Corrosion of contacts in edge connectors and integrated circuit sockets
- Movement of equipment to new location on vessel after installation

Service History - 8 Micro Computers - Representing 10 computer Years

4 Computers at Sea
2 Computers on Piers
2 Computers in offices

- Dislodged cable inside machine - repaired by user with advice by phone
- Bad keyboard "3" resulted in "33" - replace keyboard in shop
- Out of spec memory chip - 3 times - replaced 3 memory boards in shop

- bad software diskette - problem fixed by phone
- bad logic board printer -board replaced with printer in place - service call

- bad servo motor printer - 2 times - motor replaced with printer in place - 2 service calls

9 Failures out of about 5,200 hours total operation

Time between failures 577 hours of operation

Excluding trivial problems

6 Failures out of 5,200 hours

Time between Failures 866 Hours

Note trivial failures can cost same as real

applications. The most troublesome component was the printer, responsible for 30% of the problems experienced. This experience is felt to be typical. Reliability of unmodified microcomputers is probably greater than that of most electronic gear aboard ship.

6.5 Recommended Changes and Improvements to T&S Format (Presentation)

Three general principles govern the adoption of perceptually optimal formats for T&S booklets. In the first place, the relationship between the lengths of *time* required to select an entry, or read a value from a graph, and the *number* of entries or intervals is linear, at best. Inessential entries or information in the components of the T&S booklet lengths the time required for computation. It may also increase the probability of selecting an incorrect quantity or value, and thereby void a lengthy subsequent calculation. Secondly, the format must be selected with full awareness of the conditions under which it will be used. It is, for example, an oversimplification to specify a minimum typeface size based upon knowledge of the standard of corrected vision required of seafarers. The common type and quality of lighting available on ships must be known, together with interacting factors. It has been established that vibration aggravates the effects of poor lighting on users' ability to read test material. On the majority of ships visited, the possible sites for use of the T&S materials were poorly lit, and vibration from cargo operations, auxiliaries, and/or main engines would be

permanently present. Allowance must be made for this interactive effect. Finally, the accuracy of reading is directly related to the physical clarity of the material: the extent of inaccurate use is proportional to the degradation of the print. Knowledge of the pattern in a table or graph obviously has a compensating effect, but this may be minimal in the case of new types of vessels such as SEABEEs or LASH vessels, with their unconventional hydrostatic and required GM curves.

The sequencing of the instructions and component graphs/tables of the T&S booklet should minimize the possibility of entries having to be carried in the user's head. Psychologists' theories of the extent and character of the short term memory are changing, but short term memory capacity remains a limiting factor in sequential operations. Only a few (~7-12) figures or entries can be accurately recalled in the correct order, unless a note is made or the figures are rehearsed subvocally. Neither procedure should be made necessary by the organization of the T&S booklet. A layout which forces the mate to remember page numbers as well as entries, or to take additional time to write everything down, will be unsuccessful or ignored.

These are the principles which underlie the 'Format' entry on Table 14, T&S Booklet Evaluation Checklist. They can be practically expressed in a number of guidelines.

1. The size of the T&S booklet and trim/strength/ stability worksheet should be related to the characteristics of the subtables or operational sequences which need to be grouped on one page.
2. The tables and pages of the booklet should

be oriented the same way: vertically, when feasible.

3. Reference tables should be on the left-hand side of pages; those with workings, which may be copied for other entries or for records, should be on the right-hand side of the page.
4. Lettering should be 10/12 or its equivalent on a Selectric; figures should be 10 point and ranging; typeface should not be condensed, light, or italic; distortion resistance should determine the choice.[1]
5. The booklet should be printed on non-glare paer with $\geq$70% diffuse reflectance, using black ink[2] and a process which gives very clear reproduction[3] and is fully fade-resistant.
6. Explanatory notes, headings, legends, and diagrams should be repeated on every page to which they relate and set in bold face where this would assist the user.
7. Each page should be marked with the vessel's name and O.N., numbered as "such and such out of so many pages", and dated.
8. The booklet should be protected by a spring or screwed binder.
9. Grids should employ dashed, solid, and variable thickness lines to guide the eye horizontally and vertically, and to demarcate separate columns and calculations.
10. Curves on graphs should be distinguished from

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[1] Reynolds (1979).

[2] Williams, C. (1967).

[3] Reynolds (1979).

one another and from the grid by appropriate use of different types of lines, and instructions should be tied to them by wavy arrows.

<u>Recommendation 1</u>

The use of an oversize format for the stability, trim and strength calculation sheets, if not for the booklet itself, may be implied by the layout chosen for the calculations. The use of oversized formats allows the tables and workings needed for each calculation to be displayed on one page, and also permits the main calculation to be physically separated from subsidiary calculations. This serves (i) to reinforce awareness of the purpose of stability assessment, and (ii) to foster a more confident approach to the process. The one operator who had tried an oversize format in the T&S booklet itself found it too bulky, and had to issue a supplementary pocket reference. The trade-off between a cheap, slightly bulky 8 1/2" x 11" booklet, and an oversize booklet or oversize worksheet, depends upon the vessel's trade and the complexity of the cargo space and weight data.

The size of the T&S booklet has been and will probably continue to be constrained by the production methods available. Given the existing attitudes toward the booklet, xerography is probably the most suitable production method. Xerographically-produced T&S booklets can measure up to 14" x 25" on standard machines, which is sufficiently flexible to permit outside page layouts for T&S booklets of ships with restricted numbers of cargo compartments and loading conditions, but may be cramped for displaying stability data for container and barge-

carrying vessels.

Recommendation 2

Orienting all pages, graphs, and tables in the same way minimizes the time needed to find and read the values and figures required for the various calculations which make up the process of stability assessment. It also permits the 'safe' zones of various graphs to be made physically coincident. The (upper) right-hand portion of the table of vertical moments and the curve of required GM, for example, are zones of acceptable stability, and consistent identification of right-hand locations as safe or correct could prevent an unfamiliar user from misinterpreting a novel type of graph.

Consistent orientation is one of the many ways in which (i) the logic of an operation can be expressed and supported in the written instructions, and (ii) the process of stability assessment can be safely speeded up.

Recommendation 3

Results or quantities to be transcribed should be able to be compared accurately and quickly with the originals. There should be no necessity to search a page for the value to be checked, isolating and verifying it, before storing it in the short term memory, in order to effect a comparison. Moving the eyes from the right-hand side of the page to an adjacent loose sheet, in an overall vertical movement, is faster and more accurate.

Recommendation 4

Typographical aspects of the T&S booklet which can be separately optimized are the weight and form of the typeface, the use of case, and the type size and leading/spacing.

The form or style of the type includes such aspects of the overall appearance as the differential thickness of component lines, and serifs. A given typeface usually is available in a range of weights and forms, which constitute a "font". Medium typefaces are clear and more reproducible than extremes, such as condensed, light, or italic faces. Specialist faces are suited only for emphasis, as they may be difficult to perceive correctly (particularly in the case of numerals) and their unfamiliarity disrupts perception since components of the T&S booklet are copied repeatedly, copies from copies, using machines which introduce varying degrees of distortion and image degradation, resistant typefaces such as Times Roman (modern serif) and Medium Univers (sans serif) are generally satisfactory. Research to date[1] supports equally the general superiority of Modern serif or sans serif.

Sans serif typeface is used for many notices which must be read quickly, but is still uncommon in the marine world. This may be why it met with a mixed reception in the workshops. No conclusive evidence emerged for masters' preferences regarding stylistic aspects of booklet presentation.

Except in short passages, deliberately emphasized by use of all upper case, lower case letters with initial capitals are most effective in conveying the sense of the message, and minimizing the number of eye fixations and regressions needed for full comprehension. This is probably due to the presence of additional clues to the letter forms in the lower case (i.e. ascenders and descenders). Since the process of reading text is one

[1] Reynolds (1979).

of word recognition, rather than letter recognition moderate serifs probably assist the reader.[1] They appear to link the letters into a more quickly and accurately perceived word form without fusing them. It would also seem possible that serifs constitute redundant information about the letter forms, to use the language of information theory, and thus serif letters require less time for correct strong slat serifs, however, should be avoided. In the final analysis, the choice of type form is restricted by the production method to be employed.

Figures can be ranging - 12345 - or nonranging - 12345. The latter style is generally unacceptable in technical material, because it draws the lines of figures closer together and predisposes the eye to wander, either up or down, and select an incorrect value. The figures in the T&S booklet should always be typed (in one typeface, even if inserts are made). Particular attention should be paid to the reproducibility and clarity of printed figures because of the lack of reliable cues for resolving ambiguity. The figures in a 10-point Selectric font are adequately discriminable, since numerals are visually 'larger' than letters, and more resistant to degradation.[2]

Avoiding unnecessary figures is an important consideration. Accurate interpolation into five parts is felt to be within average ability; thus 1% accuracy could be theoretically obtained from twenty figures. Interpolation appeared to the respondants in the present study to offer scope for error, however, and it should only be required where uncluttered scales are important,

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[1] Bart (1959).

[2] Spencer et al (1977).

e.g. on graphs. On tables, the numbering should be ones, twos, fives, or in multiples or submultiples of these by 10 or 100 (rather than threes, fours, and other intervals).

Letters should be 10-point, on 2-point leading or the equivalent in a Selectric font.[1] 10/12 is considered an 'average' size by book designers, and smaller sizes are probably too small under the conditions aboard ship. The counters - enclosed areas of type such as centers of e's and o's - tend to fill in after successive reproduction if a smaller size is used. This recommendation applies equally to all Modern typefaces, examples of which are shown in Table 59.

Recommendation 5

Most booklets reproduced from blueprints or by a reverse blueprint process are illegible. So were some electrostatic copies of typewritten stencilled originals. Almost all the examples duplicated on ordinary paper used too light a quality, which led to 'show through'. This decreased legibility, particularly after successive electrostatic reproduction.

While it is likely that most T&S booklets actually furnished to ships are of better quality than the often specially reproduced copies examined in this study, it is possible that loss of, or damage to, the original might leave the ship using an illegible booklet, copied from a 1st, 2nd, or later copy.

Recommendation 6

Headings, diagrams, profiles, or plans, and notes

[1] Bart, op cit.

TABLE 59 - TYPEFACES

Courier 72 Code 015 — **10 Pitch**

IBM COURIER 72 Type is a square-serif design in the Pica family of type styles. The open spaced characters make it highly legible.

ABCDEFGHIJKLMNOPQRSTUVWXYZ []@#$%¢&*() 1234567890

abcdefghijklmnopqrstuvwxyz -_=+!°"'/?:;,.

Pica 72 Code 008 — **10 Pitch**

IBM PICA 72 Type is similar to the Pica type styles offered with the IBM Model D Typewriter. It is well suited for a variety of typing jobs.

ABCDEFGHIJKLMNOPQRSTUVWXYZ []@#$%¢&*() 1234567890

abcdefghijklmnopqrstuvwxyz -_=+!°"'/?:;,.

Note ranging numerals

Advocate Code 050 — **10 Pitch**

IBM ADVOCATE Type is a square-serif design in the Pica family of type styles. It is ideal for routine correspondence and reports.

ABCDEFGHIJKLMNOPQRSTUVWXYZ []@#$%¢&*() 1234567890

abcdefghijklmnopqrstuvwxyz -_=+!°"'/?:;,.

Letter Gothic Code 005 — **12 Pitch**

IBM LETTER GOTHIC Type is one of the Artisan family of type styles. It is well suited to a variety of typing jobs, especially good for correspondence and reports.

ABCDEFGHIJKLMNOPQRSTUVWXYZ []@#$%¢&*() 1234567890

abcdefghijklmnopqrstuvwxyz -_=+!°;:'",.../?

should accompany every item in the T&S booklet. These should be every provision for visual aids to the user, who may be prevented from exercising his ordinary levels of skill and care by many factors. Over-reliance on terminal figures, fatigue, distraction, and 'saturation' with arrival paperwork - overtime, official letters, planned maintenance and repair work, etc. - all tend to occur periodically, and emphasize the need for inbuilt reminders and checks of various forms.

Recommendation 7

The T&S booklet may be damaged or cannibalized. A detailed page and vessel identification must be on every sheet so that the lost/damaged pages can be identified and replaced. Where the draft booklet is finalized to become the T&S booklet, or where there have been several revisions, the revision number must be noted on the revised pages, and all pages must be marked as being current as of the date of the last revision. There must never be any doubt of the completeness and recency of any page of the T&S booklet. In any case where non-negligible changes have been made, the advisability of exchanging, rather than correcting, the booklet should be considered.

Recommendation 8

Most of the booklets examined for this study were flimsy paper, stapled. Several had lost covers. A binder which holds the pages firmly and permanently along with their full length - not a three-ring or an ACCO binder - is a necessity if the booklet is to survive the more frequent reference which is one object of this study.

Recommendation 9

Data organization in many areas - accounting and cartography, for example, employs special conventionalized grids and color codes to keep tabular displays comprehensible and to minimize the time spent in searching for particular entries/targets. The T&S booklet would benefit from the introduction of similar conventions. Some booklets presently use computer printout paper, with its potentially helpful bands of contrasting color. This gives the booklet rather an unfinished appearance, however, and does not always copy clearly. A range of possibilities should be evaluated, including the dotted and solid lines of the USCG format for the inclining experiment. The role of the grid is particularly important in the development of a supportive worksheet format.

Recommendation 10

Since interpolation by eye into five parts is a general ability, there is no reason for 'busy' graph paper. There should be a clear distinction between the lines of the paper and the curves, and it should be achieved by a method capable of copying satisfactorily. Interference from identification or instructions on curves, or from arrows linking these to their respective curves, should be minimized by judicious placement and the use of broken or wavy arrows.

7.0 UNRESOLVED QUESTIONS

Many of the recommendations of Section 6.0 are normative, with major institutional and practical implications which should be noted and briefly discussed in this section. The advantages of particular formats, and particularly of a dramatically altered and compressed T&S booklet format, are related to the structure and effects of initial and professional training, to the official emphasis placed upon stability assessment, and to the context of marine operations. The latter includes such factors as the prevalence and type of electronic calculating aid, the pressures toward international standardization, and perceived scope for owners' influence on documentation of operations.

7.1 Standardization, Criteria, and Owners' Preference

Standardization along emerging international lines (see Tables 60 and 61) has limited intrinsic advantages. Like any form of standardization, standardization of booklet content and format makes vessel transitions easier, and fosters a "feel" for correct results which helps to generate confidence and reduce the requirement for checking computations. Vessels which are sold or reregistered seldom have their original documentation revised, and a degree of standardization means that the officers can rely on finding the specific information, which they regularly use, actually aboard the vessel, in a predictable location. Standardization of units is another particularly obvious aspect of this question. Professional graphic and typographic production of specimen booklets developed by persons fully aware of the industry's needs and practice would be necessary to establish the extent to which content and format should be standardized along international lines. However, standardization which

TABLE 60 CONTENTS OF STANDARDIZED T&S BOOKLET SUGGESTED BY THE INTERNATIONAL ASSOCIATION OF CLASSIFICATION SOCIETIES

Section I

A. Compulsory Information
   1. Ship particulars
   2. Any scaled drawing
   3. The estimated total weight and center of gravity of items such as passengers and crew and their effects (per unit), vehicles, etc.
   4. Tables of capacities and centers of gravity for every compartment
   5. Tables or curves of the effect of free surface
   6. The results of the inclining experiment, the lightship condition
   7. A diagram showing the load line, corresponding freeboards, and also displacement, metric tons per cm. immersion, and deadweight, corresponding to a range of mean drafts
   8. Complete hydrostatic particulars
   9. Cross curves of stability

B. Conditions to be described in the Stability Manual
   1. Light condition
   2. Docking condition
   3. The standard conditions stipulated in Item 1 of Appendix II to IMCO Resolution A. 167 (ES. IV).
   4. Any other condition of loading appropriate

C. Presentation of Stability
   Each standard condition of loading shall include certain details
   1. Profile, plan view diagrams showing the distribution of all components of the deadweight
   2. A calculation giving the displacement and positions of centers of gravity, free surface effects to be clearly indicated.
   3. A summary of condition showing the mean draft, displacement, longitudinal centers of buoyancy and gravity, trimming moment, trim calculation, draft at after and forward perpendiculars and, if necessary, draft in way of draft marks.
   4. A summary of initial stability including the calculation of GM with and without free surface effects; a curve of righting levers (GZ) corrected for free surface effects.

Section II.

A. Data to assist the master in evaluating corrective heeling moments based on subdivision and damage stability

B. Information, a precalculated diagram, enabling the Master to determine the stability in any condition of loading

TABLE 61 Department of Transportation Trim and Stability Format

Page

1. General Particulars
2. Plans showing Cargo Spaces, Storerooms and Tanks
3. Special Notes Regarding the Stability and Loading of the Ship
4. Metric Conversions
5. Hydrostatic Particulars
6. Capacities and Centres of Gravity of Cargo Spaces, Storerooms, Crew and Effects
7. Capacities, Centres of Gravity and Free Surface Moments of Oil and Water Tanks (sheet 1 – Cargo Oil and Oil Fuel)
8. Capacities, Centres of Gravity and Free Surface Moments of Oil and Water Tanks (sheet 2 – Engine Room and Fresh + Ballast)
9. Notes on use of Free Surface Moments
10. Container Ships – capacities and centres of gravity
11. Cross Curves of Stability (KN Curves)
12. Example showing use of Cross Curves (KN)
13. Deadweight Scale
14. List of Conditions required
15. Typical Condition Sheet
16. Statical Stability Curve for Condition

Simplified Stability Information

17. General Note
18. Deadweight Moment Curve + Table
19. Typical Loading Sheet

Damaged Stability

20. Flooding and Damaged Stability; requirements for Type 'A' and Type 'B' ships
21. Flooding and Damaged Stability; requirements in the flooded condition
22. Flooding and Damaged Stability; information to be presented from flooding calculations
23. Flooding and Damaged Stability; typical sketches required

Source:

is fundamentally unwelcome to the master and mate will simply mean that the source of operating guidance will not be the T&S booklet.

The choice of stability criterion is a problem allied to this issue, although separable. The suggested table of contents promulgated by International Association of Classification Societies incorporates and is compatible with a GM-based stability criterion, whereas the British Department of Trade booklet, which is representative of many European countries; approaches, employs a righting arm criterion. This study has made no attempt to determine what a knowledge of further stability criteria would add to masters' and mates' practical skill and confidence levels. Even the pared-down booklet incorporates a GM-based criterion, along with cross curves for construction of righting arms, should that become necessary. That it does become necessary occasionally is one definite conclusion of the present effort. One master, in the course of a long interview at MITAGS, recounted his experience in attempting to save life in a storm. His vessel heeled so far during the attempt that he concluded he was risking the lives of his crew, and the rescue had to be abandoned. Had he been able to assess his reserve stability in a quick, reliable fashion, his decision might have been different.

Many owners and owners' representatives commented in the course of the study on their desire to retain company formats and other special features in the booklet. In only one case was this found to be consistent with their masters' and mates' desires. (Generally, the officers were indifferent.) The company concerned has a unique operation, and in-house staff whose efforts have developed particularly simple, well-adapted materials. The majority of owners who professed attachment to their

existing T&S booklet formats in fact had formats very similar to others produced by the shipyards concerned. This issue, although an emotive one, has little basis in fact. The expected savings in production cost of a range of standardized booklets would probably overcome the shipowners' present common distaste for the idea.

7.2 The T&S Booklet and Other Reference Material Aboard Ship

The T&S booklet is one of several sources of information about vessel operation. There are capacity plans, deck officer's handbooks, loading manuals, vessel characteristics pamphlets, maneuvering data, and a full outfit of plans, in addition to the booklet. These can complement the booklet or compete with it, depending upon how functional the booklet is. This situation reflects the historical development of shipping regulation, and can not be rationalized overnight, nor is there a clear basis on which to effect rationalization. The urgent questions at present are rather, what should appear in the T&S booklet - specifically, where is the division between maneuvering data and cargo operations data? where should excerpts from the booklet appear? should the booklet be duplicated (e.g. combined with the loading manual as well as filed separately with the plans)? What should be the relationship between booklets required by the Coast Guard (responsibility for stability and trim) and ABS (responsibility for vessel stress assessment)? The latter is a particularly important question, since newbuildings, and retrofits of certain ages, are provided with loading manuals as well as T&S booklets. The two books overlap operationally, but reflect different concerns and are developed by different bodies. The Coast Guard is a regulatory body concerned with load lines and inspection

requirements, and its legitimate concern is transverse stability and trim, while, ABS, as classification society, evaluates vessel strength. Even where the loading manual and T&S booklet are *combined*, the Coast Guard's legitimate concern is restricted to the areas previously mentioned, although there is a possibility of confusion in the coexistence of operationally important Coast Guard and ABS materials. Operators were divided on the advisability of comvining the two, or having a Coast Guard review of each case to determine that the documentation is consistent in format and basis of calculation. Regulation of the loading manual would be unfavorably regarded, in the existing climate of industry opinion, which is against regulatory and legislative interference. Several respondants criticized the imposition of operating instructions on top of the requirement for specified GM. Owners' preferences will enter largely into this issue. There should, however, be an effort made to ascertain that the relationship between the booklet and manual is functional, without increasing the burden of regulation on industry or Coast Guard.

7.3 Work Structure of the Ship and Achievement of Professional Competence in Stability Assessment

In the structured working community of the vessel, stability responsibilities are assigned to the master (legal responsibility) and the chief officer (functional responsibility).

It is questionable whether this rigid demarcation of duties is the best way of dealing with stability assessment, or indeed or organizing any work aboard ship. There is normally little need for junior officers to concern themselves with stability, yet it is necessary and highly desirable that they should build up familiarity

and confidence in the task of stability assessment during their sea service. Proficiency in computation of stability and stress would enable junior officers to manage their cargo operations responsibilities more efficiently and support the master and mate in their function. The assignment of formal responsibility for stability assessment to the master and mate is a poor preparation for emergencies and makes the inclusion of stability instruction in academy syllabi rather wasteful of college time.

7.4 Teaching of Stability and Standardization of T&S Materials

The teaching of stability would be benefitted and rationalized by standardization of booklets. More pertinent and interesting instructional materials could also be developed. The academy courses could be better related to opportunities for practice and self-instruction if work group structures were flexible and booklets were standardized. These changes would be consistent with and support the idea of more onboard training for all ranks during sea service.

7.5 Electronic Aids

The proper scope for electronic aids is a very critical issue, beyond the scope of this effort, but requiring the Coast Guard's attention. There is a possibility of cheaply and reliably automating stability and stress computations, and other basic skills, as well as storing official documentation in computers. This can be implemented without erosion of basic skills - indeed, it can add additional skills to the mariner's repertoite - but this would be conditional on a thorough change in existing attitudes and legal regimes.

It was the contractor's understanding that electronic aids were to be independent of the booklet, and accordingly, limited recommendations have been made in Section 6.0 on this issue. Members of the contractor's staff feel strongly that all new construction which requires a trim and stability booklet should be supplied with a microcomputer to calculate stability. The computer's program should be used to generate the examples in the T&S booklet, using realistic voyage data if feasible. Prompt development of a policy is required, so that marine automation can be guided and attain respectability based upon confident usage.

7.6 Coast Guard Review

A final unresolved issue is the scope for improving the Coast Guard review process. The result of Coast Guard review is perceived by the industry as unreliable. Four instances of serious error were demonstrated by a naval architect, a highly sophisticated chief mate, a terminal supervisor, and a head of vessel management, respectively. The booklets had been approved in more than one district, and the types of error were different - incorrect VCGs, inaccurate methods, general, but cumulative, inaccuracies. The contractor has reviewed some correspondence between the districts and the booklet designers, and is at a loss to explain why the errors escaped detection, or indeed why there should be such an adversarial attitude in the process of developing the T&S booklet. This attitude could be an obstacle to implementing recommendations of the present report.

APPENDICES

1. INSTRUMENTS AND RESPONSE SCHEDULED AND WORKSHOP MATERIALS

    1. Form letter announcing the study
    2. Grading rationale for IOMMP-sponsored test of stability knowledge
    3. First workshop materials
    4. Second workshop materials

2. STATISTICAL TREATMENT OF WORKSHOP RESULTS

3. THE PHYSICAL AND COGNITIVE BASIS OF GOOD FORMAT

4. BACKGROUND TO FORMAL STABILITY INSTRUCTION

    1. International Law Governing Merchant Marine Officer Training
    2. Evidence Regarding Academy Entrants' Ability. Both from the Evidence of the Oversight Report on the Federal Government's Role in Merchant Marine Officer Education. Ad Hoc Select Subcommittee on Maritime Education and Training of the Committee on Merchant Marine and Fisheries, Serial No. 95-E, 1978.
    3. Stability Related Courses at Merchant Marine Academies, from Merchant Marine Academy brochures, 1978-79, and course notes and outlines provided by academy instructors.

APPENDIX 1

1. Form letter announcing the study

2. Grading rationale for IOMMP-sponsored test of stability knowledge

3. First workshop materials

4. Second workshop materials

E. G. Frankel Inc. - E.G.F. International
Consulting Engineers, Economists and Transportation Analysts
52 Bay State Road
Boston, Massachusetts 02215
Telex 940397 • (617) 536-1060

FORM LETTER SENT TO TRAINING INSTITUTIONS AND MARITIME ACADEMIES

Dear Sir,

Investigation of Officers' Understanding and Use of Ships' Stability Information

Project Director: Professor Ernst G. Frankel, MIT

The U.S. Coast Guard has determined that an effort is required to investigate the format and presentation of stability information, and its adequacy, in light of the evolution of ship types and the consequent complexity of stability calculations. It is thought that the necessity for real time stability information on new vessel types may require optimized formats for trim and stability booklets and loading manuals, and the development of modified methods of calculating stability. A contract to perform this work has been awarded to us, and we are anxious to secure your cooperation.

The value of this study will be in direct proportion to the range of facts, opinions, and suggestions we are able to elicit and incorporate in our proposals. With respect to many aspects of shipboard stability calculation, no conclusive, nationally valid feedback is available to guide the Coast Guard, the Classification Societies, or the staffs of maritime academies, whose work it is to maintain and raise the professional standards of merchant marine personnel. There is also a lack of a defined baseline for officers' knowledge and use of shipboard stability information. Accordingly, we would initially like to collect and analyze data on the teaching of stability in the maritime academies, and the examination performance of undergraduates. Subsequently, we will examine the interplay between officers' initial training and subsequent upgrading, the characteristics of the shipboard stability outfit, company policies on shipboard aids, and ship/shore division of stability calculations, concentrating on exploration of officers' understanding and use of

existing trim and stability information. Our goal is identification of optimal T&S booklet and loading manual formats, and calculation methods.

We would ask you to consider providing the following information. Please be assured that we are only asking for *summarized* information, *not for details of individuals' records*. Your information will be held strictly confidential, even from the study's sponsors. The function of these details is to indicate (i) the methods which graduates have been taught to use in stability calculations, (ii) the strengths and weaknesses of graduates' knowledge of stability principles, and (iii) the scope which remains for self-instruction and license upgrading courses. We would ideally like the opportunity to see

- the present (and former, where applicable) syllabus of the academy's course(s) on ship stability
- the reading list for the course, together with any outlines, notes, or assignments pertaining to the course
- specimens of past and current internal examinations in stability
- any analyses of students' success in these exams, which would indicate - for example - how stability grades corresponded with overall average grades, whether any particular aspects gave difficulty, or how a change of syllabus affected patterns of achievement

In addition, any comments from the staff - on the directions the study might take, or the type of changes which might be desirable (or contemplated) in the teaching and application of stability principles, or on any other topic relevant to our effort - will be highly welcome and acknowledged in the Final Report. It is impossible to overemphasize the value of receiving opinions from every institution and professional group in the maritime community.

We look forward to hearing from you. Should you wish to discuss the application or safeguarding of your information before making a written reply, please contact

us between 08.00 and 16.00 at (617) 536-1060. We will be happy to answer any questions or elaborate on this brief description of a very challenging and worthwhile project.

Yours very sincerely,

E. G. FRANKEL INC.
E. G. F. INTERNATIONAL

P. G. Read
Marine Analyst

PGR:sm

2. GRADING RATIONALE FOR IOMMP SPONSORED TEST OF STABILITY KNOWLEDGE

Those whose knowledge of stability is merely adequate should get up to 50. Thus weights of 1, 3, and 7 should sum to 50 marks. 1 and 3 cover roughly the same material and have equal weight. Question 7, while very important was given weight of, 10 as only one question, leaving 20 each for 1 and 3.

Question 1. (20)

a. What is initial stability?
b. What is indicator of initial stability?
c. To what heel angle is GM valid?
d. Does negative GM mean vessel will capsize? Can such a vessel be stable at large heel angles? What is minimum result of negative GM?
e. What are principal factors in initial stability.

Question 3. (20)

a. Can you state the formula GZ = GMsineθ in words?
b. Why does one wish to know length of the righting arm?
c. What is the measure of stability?
d. GM and GZ can decrease, yet stability increase. T/F

Question 7. (10)

Free surface effect depends on....

NG: Within these questions, the most subtle was Question 3e, knowledge of role of displacement in stability, which received 10 points.

Those who understand technical material sufficiently to knowingly comply with regulatory requirements should get up to 75. Hence questions 2 and 4 = 25. Question 2 is more important: hence, 15 for 2 and 10 for 4.

Question 2. (15)

What are cross curves of stability?
What is their purpose?

Question 4. (10)

a. What is dynamic righting arm curve?
b. What is its purpose?
c. What information does it give you?
d. What controls range of stability?

This leaves 25 points for 5, 6, and 8. Question 6 is least important and it receives only 5 points. Questions 5 and 8 indicate roughly equal levels of comprehension and get equal weights.

Question 6. (5)

a. What is the distance BM called?
b. Why would you wish to know BM?
c. On what does the value of GM depend?
d. Why does KM decrease and then increase with draft?

Question 5. (10)

a. What does Figure 1 assume?
b. How do stability curves reflect more of the cargo?
c. What is term for area C on Figure 4?

Question 8. (10)

What factors besides handling cargo strongly affect GM?

FIRST WORKSHOP MATERIALS

BACKGROUND INFORMATION SHEET

RANK: Master __________
Chief Officer __________
Second Officer __________
Third Officer __________

HIGHEST LICENSE: Master __________
Chief Officer __________
Second Officer __________
Third Officer __________

LAST/PRESENT COMPANY: __________

LAST VESSEL'S NAME: __________

TYPE: __________

USUAL TRADE OR ROUTE: __________

HOW DID YOU QUALIFY TO SIT FOR YOUR FIRST LICENSE?

service in the ranks __________
merchant marine academy __________
union school __________
other (specify) __________

DID YOU TAKE ANY CLASSROOM COURSES ON STABILITY OR STABILITY-RELATED SUBJECTS? __________

if so, where? __________

how long did the course last? __________

what was your opinion of the course? __________

____

____

____

EDUCATION

college __________
high school __________
primary school __________

1. a. What is initial stability?

b. What is the indicator of initial stability?

c. Up to what approximate degree of heel is GM a valid indicator of stability?

d. Does negative GM mean that the vessel will capsize easily?

A ship with negative GM can nevertheless be stable at large angles of inclination. T / F

What is the minimum result of negative GM?

e. What are the principal factors in initial stability?

2. Examine Figure 1.

a. What are these curves? What do these curves represent?

b. What is their purpose?

3. Examine Figure 2.

   a. Can you state the formula ($GZ = GM \sin \Theta$) in words?

   b. Why do you wish to know the length of the righting arm?

   c. What is the measure of stability?

   d. GM and GZ can decrease, yet stability can increase.
   T / F

4. Examine Figure 3

   a. What is this?

   b. What is the purpose of this curve?

   c. What information does it give you?

   d. What controls the range of stability and/or the dynamic stability of a vessel?

5. a. What does Figure 1 assume?

   b. Using Figure 4, please explain how the stability curves on the right reflect the movements of cargo.

   c. What is the term for area c on Figure 4?

6. Examine Figure 2.

   a. What is the distance BM called?

   b. Why would you wish to know BM?

   c. On what does the value of BM depend?

   d. Why does KM decrease and then increase in value?

7. Free surface effects depend on....

8. You get a change in GM as cargo is loaded or discharged. What other frequently encountered operational conditions produce change in GM?

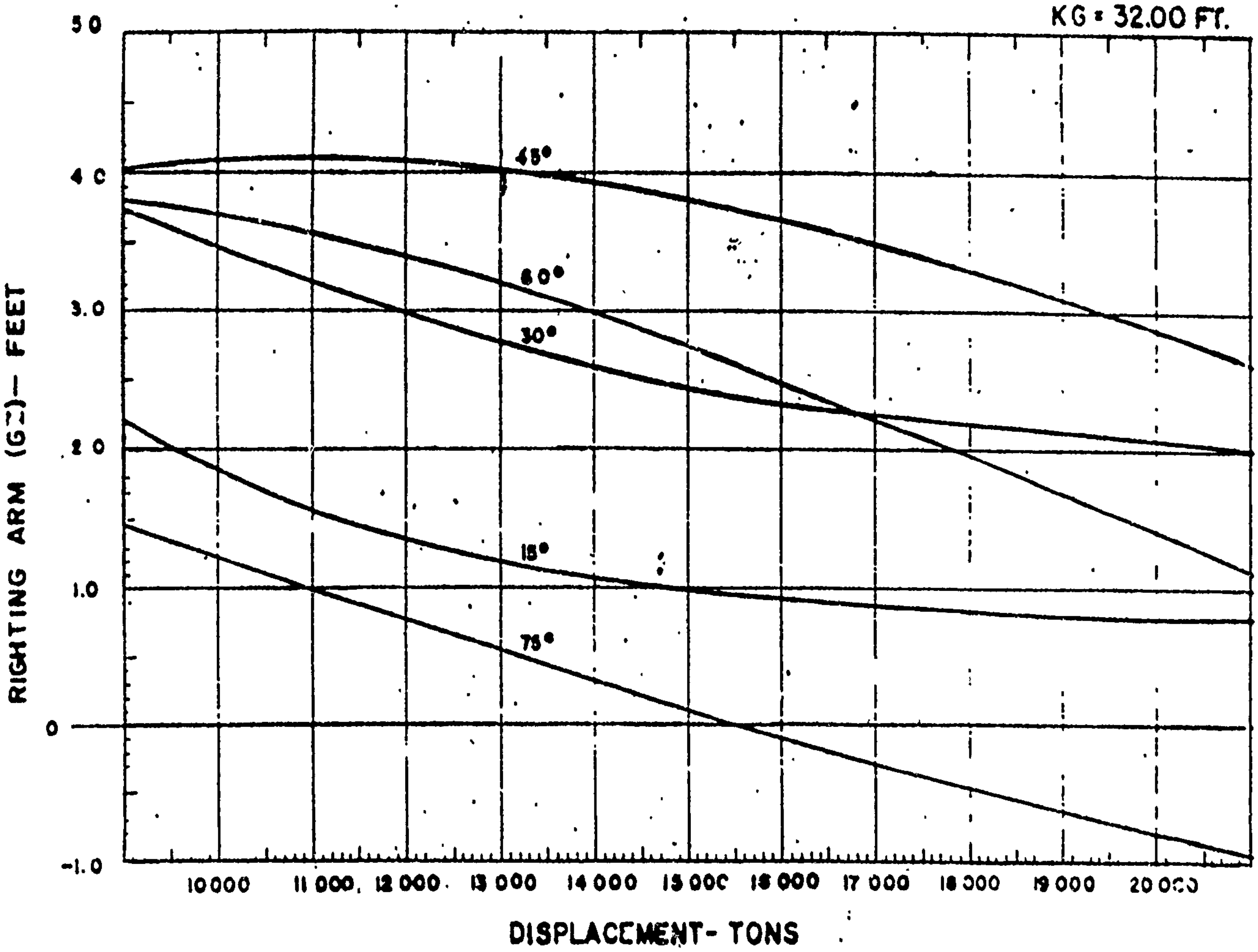
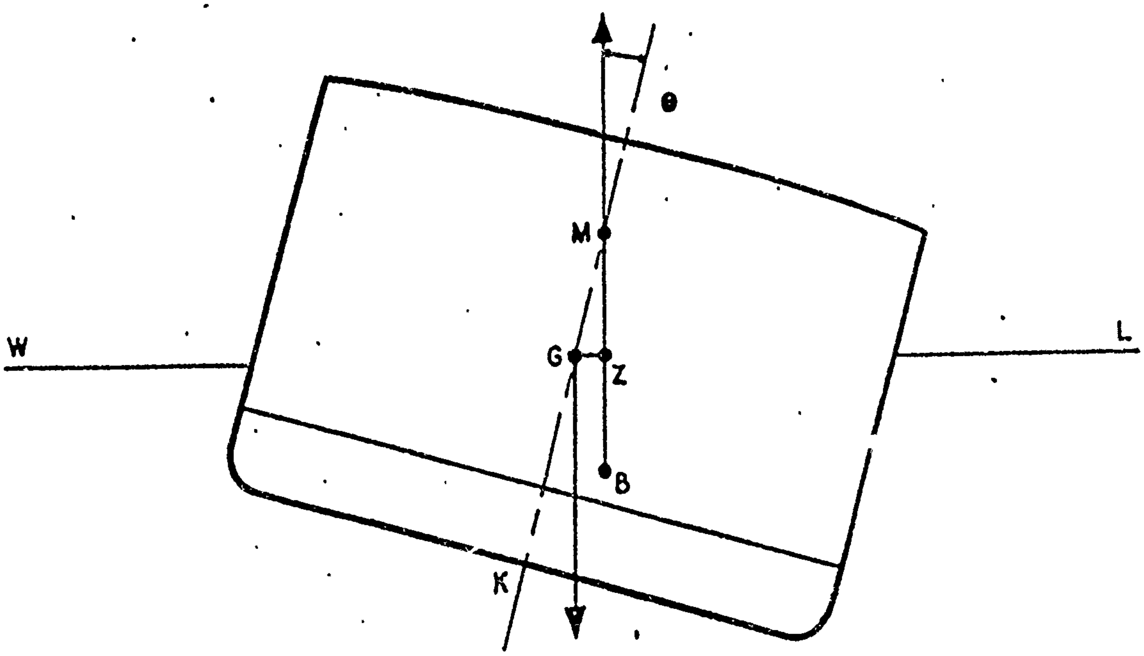


FIGURE 1



$GZ = GM \sin \Theta$

FIGURE 2

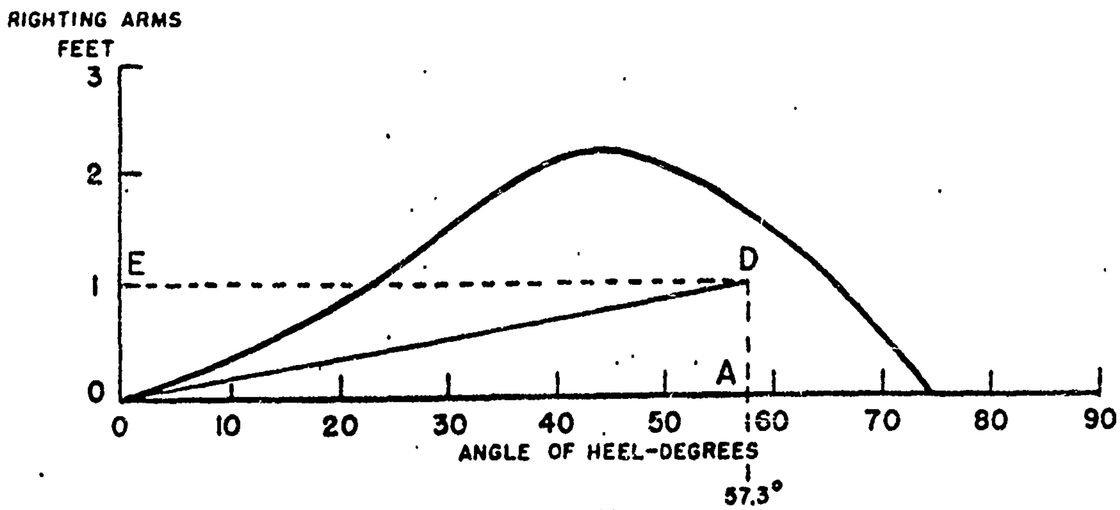


FIGURE 3

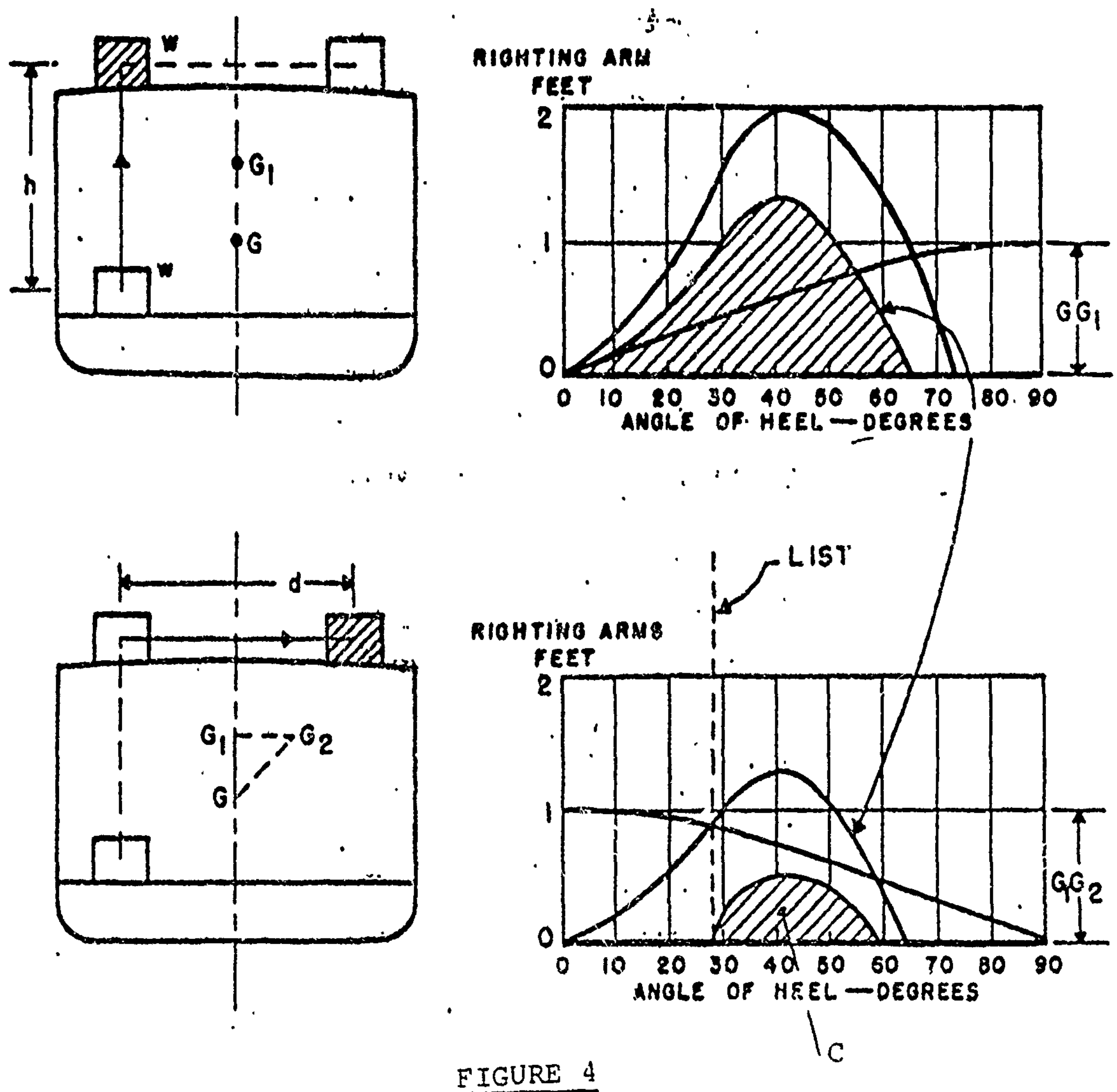


FIGURE 4

USAGE QUESTIONS

1. Has the table of ship's principal characteristics been useful to you in *calculating* stability?

2. Has the table of lightship condition been useful to you in *calculating* stability?

3. What is your opinion of the operating and general instructions which are included in every T&S booklet?

4. The graph of required GM reflects several stability criteria; there may be more than one curve of required GM. Is the graph explained to your satisfaction?

   (follow-up question: What explanations would you like to have?)

5. Are the graphs and tables of the T&S booklet reproduced adequately?

6. Is the trim table of use to you in planning loading/weight transfers?

   (follow-up question: What are the shortcomings of this table?)

7. Is the table of gain in GM of use to you in planning loadings/weight transfers?

(follow-up question: What are the shortcomings of this table?)

8. Have the sample loading conditions been useful to you?

How many do you like to see included in the booklet?

9. What is your opinion of the $\begin{Bmatrix} \text{bending moment calculation} \\ \text{calculation form} \end{Bmatrix}$ included in the T&S booklet?

10. Do you refer to the T&S booklet for cargo space and capacity data <u>or</u> do you use the ship's loading manual?

11. Does it seem important to you that all tables and graphs should be oriented the same way - that is, laid out on the page so that they all read down, or all read across?

12. Would you like more diagrams, ship profiles, or other graphical aids in the T&S booklet?

(follow-up question: Where would you like such illustrations?)

GENERAL QUESTIONS

1. What do you feel are the purposes of stability calculations aboard a ___________ ship? (pause for reply) Were there any other objectives which were achieved by the master's/your knowledge of the ship's stability?

2. Did the ship's owners have any additional requirements? (Probe question: Were there any requirements for minimum drafts, ballast conditions, or other requirments which related even indirectly to the ship's stability or maneuverability in the light condition?)

3. (If respondent sees a difference between any or all of these, follow with a probe question: You have said...which seems to indicate that you feel there is an overlap/a conflict between the objectives of the ship designer, the ship owner, and yourself as a master. Can you explain further?)

4. Would you tell me what you consider to be the items of stability information usually found aboard ships? (Interviewer has card with a comprehensive list of items of stability information.)
(Probe question: Do you think the (reading successive items from card) is or should be part of the ship's stability information?)

5. What is needed (or what would you require) to perform the stability calculations needed to satisfy
   a. Coast Guard requirements
   b. company requirements
   c. your criterion of operational stability

6. (a) On your last vessel, where was the stability booklet kept?

(b) How many copies did you have aboard?

(c) Was the book hard covered or protected in any way?

(d) What else was aboard in the way of stability information?

(e) What was available to calculate stability?

(f) What was aboard which described the criteria of stability?

7. Who performed the final, clean stability calculations on your ship?

8. What (a) methods
(b) raw data were used
(c) aids

Who checked stability calculations?

How was the check performed? (basis, procedure)

9. Were you ever on a vessel whose calculated stability was satisfactory, but which you felt was too tender or too light?

10. Can you describe to me from your own experience any situations where stability was a problem on a ship? What was the apparent cause of the problem and how was it corrected?

THESE INSTRUCTIONS HAVE BEEN PREPARED AS AN AID TO OPERATING PERSONNEL IN CONNECTION WITH THE USE OF THIS TRIM AND STABILITY BOOKLET.

1. The Trim and Stability Booklet Provides:-

(a)	Page 1	Title or Cover Page
(b)	Page 2	Operating Instructions
(c)	Page 3	Table of Principal Characteristics
(d)	Page 4	Trim Table
(e)	Page 5	Hydrostatic Properties of Ship
(f)	Page 6	Summary of Capacities, Their Centers and Free Surface Effects.
(g)	Page 7 & 8	Graphs Showing The Lost In "GM" Due To Flooding.
(h)	Page 9	A Graph Of Cross Curves Of Stability.
(i)	Page 10	A Table Showing Draft Marks Location.
(j)	Page 11	A Blank Sheet To Write For Vehicle Data.
(k)	Page 12	A Blank Sheet For Determining The "GM" And Trim Of Vessel.
(l)	Page 13 To 24	Work Sheets Completed At Different Conditions Of Loading.

2. PROCEDURES:-

(a) In calculating the vessels' trim and stability by the direct method for any condition of loading, the detail weights in each category such as Cargo, Crew and Stores, Fresh Water, Fuel Oil, Ballast, etc., are entered in the Loading Table, Page 12, together with the vertical and longitudinal centers for each item, likewise, appropriate free surface correction for each tank containing liquids which is not pressed up, shall be entered. The Table, Page 6, gives data for the tank capacities, centers and free surface corrections, for tanks not pressed up. In the separate detail Loading Tables, Pages 13 to 24, are work sheets, showing use of Loading Table, Page 12. The summary of each column for weights, vertical moment, longitudinal moment (moment is the product of weight by center of gravity distance for each item) and free surface effect (i/δ) are taken.

(b) The Stability Condition Sheet or Loading Table, Page 12, finally sums the tonnage (weight), vertical moment, longitudinal moment and free surface results obtained above and includes lightship values. The total tonnage (weight) obtained is the vessels' loaded displacement. The loaded vessels' KG and LCG are determined by dividing the total vertical and longitudinal moment summations, respectively, by displacement. The Salt Water Mean Keel Draft corresponding to the total displacement is read from the Table of Hydrostatic Properties, Page 5, together with the transverse metacenter (KMt), Moment to Trim 1", LCF and LCB. These values are entered on the Stability Condition Sheet, Page 12. The KG (The VCG at total displacement) subtracted from KMt gives the GM of the vessel uncorrected for free surface. The free surface correction is obtained by dividing the total free surface (i/δ) by the total displacement and is subtracted from the uncorrected GM to arrive at the corrected available GM. ("δ" is the density in cubic feet per ton of the liquid in the respective tank).

(c) The distance between the vessels LCG and LCB is the trim lever. The product of displacement by trim lever is the moment causing the vessel to trim. When such moment is divided by "moment to trim one inch" (as found from the Curves of Form, Page 5) the vessels total trim in inches as measured on perpendiculars is determined. (When LCG is aft of LCB the vessel trims aft and vice versa.) The decimal of this total trim to be applied to the fwd. perpendicular is obtained by dividing the distance from the fore perpendicular to the LCF by the length between perpendiculars. The remainder of the total trim is applied to the aft. perpendicular. Final Drafts on perpendiculars are found by applying these trim components to the mean keel draft corresponding to the displacement involved.

(d) All tons used in this booklet are long tons of 2240 pounds.

• Enter full free surface correction for the following service tanks; Fuel Oil contaminated Tanks and Settlers, Feed Water, Distilled Water, and Drinking Water Tanks. Not more than one pair of Tanks, except as mentioned shall be slack at any one time.

3. Routine Operating Instructions:-

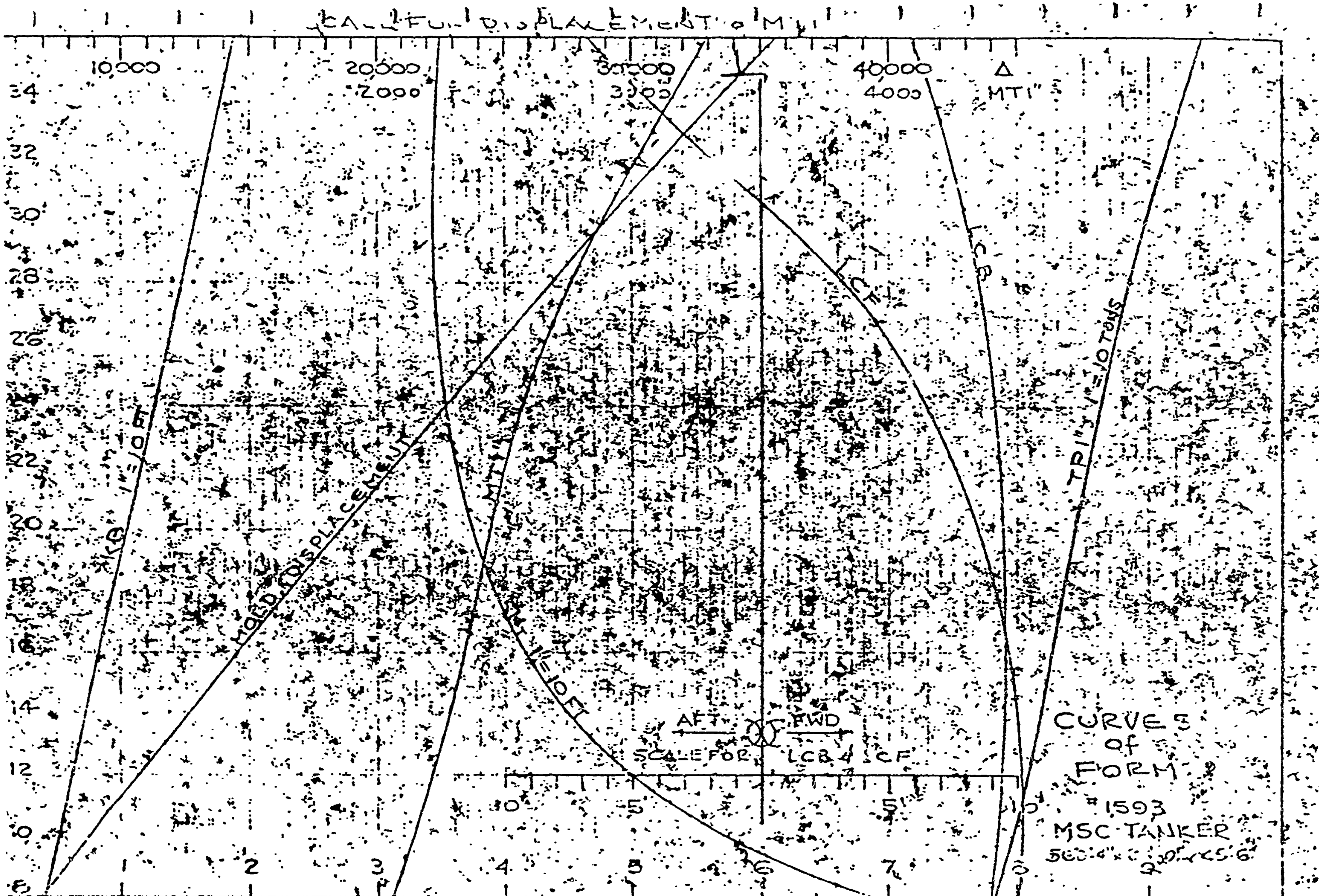
(a) During the ballasting, a reduction in the vessels GM due to slack free surface will occur until the tank is pressed up. This temporary loss in GM (in feet) is equal to the Salt Water i/δ of the tank divided by the vessels displacement (in Long Tons) at the moment. (i/δ is the free surface effect as noted on Table, Page 6).

(b) Tanks required to be ballasted with Salt Water shall be immediately filled and carried pressed up at all times while such ballast is necessary. When not ballasted, such tanks shall be kept pumped to a minimum content at all times.

(c) Bilges shall be kept pumped to a minimum content at all times.

(d) This booklet contains calculations from Page 13 to 24, illustrating the use of Table, Page 12.

(e) The Vessels operating GMs (corrected for free surface) shall at no time be less than those indicated on Pages 7 and 8.



CURVES OF FORM

HYDROSTATIC PROPERTIES

α ([illegible])	Δ (L.T.)	MT1" (FT.TONS)	TPI (TONS)	KM (FT)	LCB (+AFT)	LCF (+AFT)
24' 0"	28500	6030	139.8	62.95	27.75	49.00
3"	28900	6346	141.0	63.10	28.10	51.70
6"	29320	6490	142.2	63.15	28.50	[illegible]
9"	[illegible]	6600	143.2	63.15	28.75	54.70
25' 0"	30180	6685	144.2	63.10	29.15	55.65
3"	30600	6770	145.1	63.00	29.50	56.20
6"	31020	6845	145.9	62.85	29.80	56.60
9"	31460	6910	146.7	62.70	30.25	56.90
26' 0"	31900	6975	147.4	62.45	30.60	57.15
3"	32350	7040	148.0	62.25	30.95	57.35
6"	32800	7095	148.6	62.05	31.25	57.50
9"	33250	7155	149.2	61.80	31.65	57.65
27' 0"	33700	7210	149.7	61.60	32.00	57.75
3"	34150	7265	150.2	61.35	32.35	57.85
6"	34650	7316	150.7	61.15	32.70	57.95
9"	35100	7365	151.2	60.90	33.00	58.00
28' 0"	35550	7415	151.7	60.70	33.30	58.00
3"	36000	7466	152.2	60.50	33.65	58.05
6"	36480	7515	152.6	60.30	34.00	58.10
9"	36950	7565	153.1	60.05	34.35	58.10
29' 0"	37430	7610	153.5	59.85	34.60	58.15
3"	37900	7660	154.0	59.65	[illegible]	58.15
6"	38380	7710	154.4	59.45	35.25	58.15
9"	38850	7760	154.8	59.25	35.50	58.20
30' 0"	39310	7810	155.2	59.10	35.80	58.20
3"	39790	7870	155.6	58.95	36.15	58.20
6"	40260	7930	156.1	58.80	36.50	58.50
9"	40760	8000	156.6	58.65	36.80	58.85
31' 0"	41230	8100	157.1	58.55	37.05	59.00
3"	41720	8280	157.8	58.60	37.35	62.40
6"	42200	8440	158.6	58.40	37.65	[illegible]
9	42670	8560	160.0	58.35	37.95	64.90
32' 0"	43160	8645	162.0	58.35	38.20	65.30
3"	43620	8720	162.9	58.10	38.50	65.35
6"	44110	8765	163.3	57.90	38.75	65.30
9"	44600	8800	163.6	57.65	39.00	65.20
33' 0"	45090	8835	164.0	57.45	39.30	65.05
3"	45600	8866	164.3	57.25	39.55	64.85
6"	46060	8895	164.5	57.10	39.80	64.60
9"	46550	8926	164.8	56.90	40.05	64.30
34' 0"	47030	8950	165.1	56.75	40.30	63.95
3"	47510	8975	165.3	56.60	40.55	63.60
6"	48000	9000	165.5	56.45	40.80	63.30
9"	48500	9025	165.8	56.30	41.05	62.95
35' 0"	49000	9050	166.0	56.15	41.30	62.60
3"	49500	9075	166.2	56.00	41.50	6 .25
6"	50000	9100	166.4	55.90	41.75	6 .90
9"	50500	9125	166.7	55.75	41.95	61.55
36' 0"	51000	9150	166.9	55.65	42.15	61.20
3"	51500	9170	167.0	55.50	42.30	60.90
6"	52000	9195	167.2	[illegible]	42.50	60.55
9"	52500	9220	167.4	[illegible]	42.65	60.25
[illegible]' 0"	53010	9240	167.6	[illegible]	42.80	59.90
3"	53510	9265	167.8	[illegible]	42.95	59.60
6"	54010	9290	168.0	[illegible]	43.10	59.25
9"	54510	9315	168.1	54.85	43.25	58.95
[illegible]' 0"	55020	9335	168.2	54.75	43.40	58.65
3"	55520	9360	168.4	54.65	43.50	58.35
6"	56020	9385	168.6	54.55	43.60	58.00
9"	56560	9405	168.8	54.45	43.75	57.70
[illegible]' 0"	57080	9430	169.0	54.35	43.85	57.40
3"	57600	9450	169.1	54.30	44.00	57.10
6"	58100	9470	169.2	54.20	44.10	56.75
9"	58610	9495	169.4	54.10	44.20	56.45

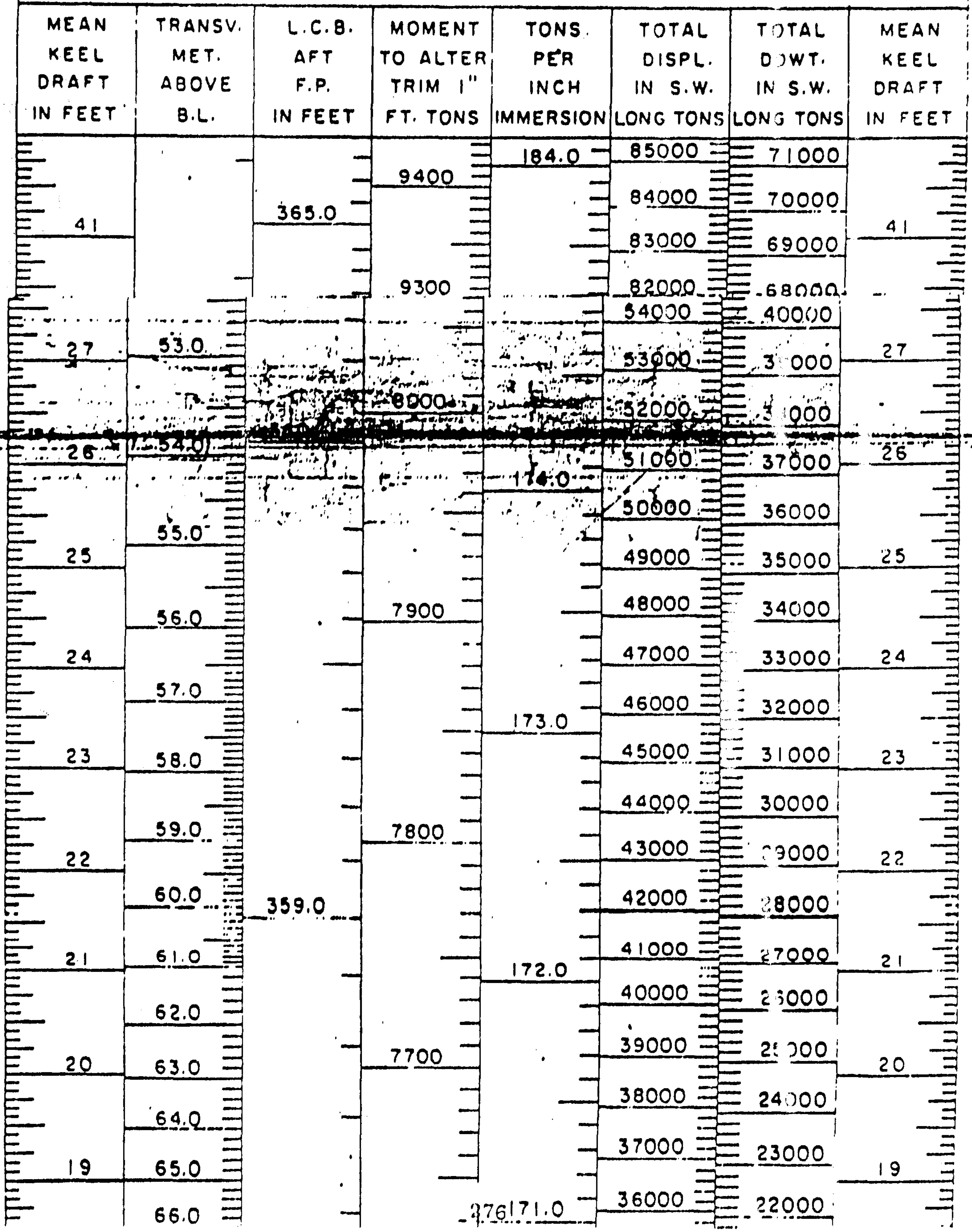
HYDROSTATIC PROPERTIES

DRAFT (BOTT. OF KEEL)	DISPLACEMENT LONG TONS	MT1" FT-TONS	TPI L.T.	KM FT	LCB (FT) + ⊗ - FWD	LCF (FT) + ⊗ - FWD
28'-0"	72650	11250	235	71.7	+0.52	-1.2
3"	73360	11270	235	71.4	+0.50	-1.12
6"	74075	11300	236	71.15	+0.50	-1.10
9"	74790	11320	236	70.85	+0.50	-1.05
29'-0"	75500	11350	236	70.50	+0.48	-1.02
3"	76200	11380	236	70.20	+0.47	-1.00
6"	76900	11440	237	69.90	+0.46	-0.70
9"	77650	11520	237	69.75	+0.46	-0.40
30'-0"	78360	11570	238	69.40	+0.45	0.00
3"	79200	11660	238	69.15	+0.46	+0.46
6"	79800	11730	239	68.87	+0.47	+0.90
9"	80500	11810	240	68.60	+0.46	+1.36
31'-0"	81200	11900	240	68.40	+0.46	+1.90
3"	81925	12010	241	68.10	+0.50	+2.70
6"	82650	12125	241	67.90	+0.52	+3.28
9"	83375	12140	241	67.60	+0.55	+3.17
32'-0"	84100	12160	242	67.40	+0.57	+3.07
3"	84825	12180	242	67.15	+0.60	+2.95
6"	85550	12200	242	66.92	+0.62	+2.85
9"	86275	12220	242	66.72	+0.65	+2.75
33'-0"	87000	12240	242	66.52	+0.67	+2.65
3"	87750	12260	242	66.30	+0.68	+2.55
6"	88500	12280	242	66.10	+0.70	+2.45
9"	89250	12300	243	65.85	+0.71	+2.36
34'-0"	90000	12330	243	65.70	+0.72	+2.28
3"	90800	12350	243	65.45	+0.75	+2.20
6"	91500	12370	243	65.30	+0.76	+2.10
9"	92200	12390	244	65.10	+0.78	+2.10
35'-0"	92980	12420	244	64.90	+0.79	+2.06
3"	93700	12450	245	64.79	+0.80	+2.05
6"	94400	12480	245	64.65	+0.80	+2.05
9"	95100	12520	245	64.45	+0.82	+2.07
36'-0"	95800	12550	245	64.30	+0.83	+2.12
3"	96500	12600	245	64.10	+0.85	+2.20
6"	97250	12640	245	63.10	+0.85	+2.28
9"	98000	12680	246	63.85	+0.85	+2.40
37'-0"	98725	12740	246	63.75	+0.87	+2.58
3"	99500	12810	247	63.60	+0.88	+2.80
6"	100250	12885	247	63.50	+0.90	+3.10
9"	101025	12970	248	63.30	+0.91	+3.35
LOADLINE 37'-10"	101200	13010	248	63.25	+0.92	+3.50

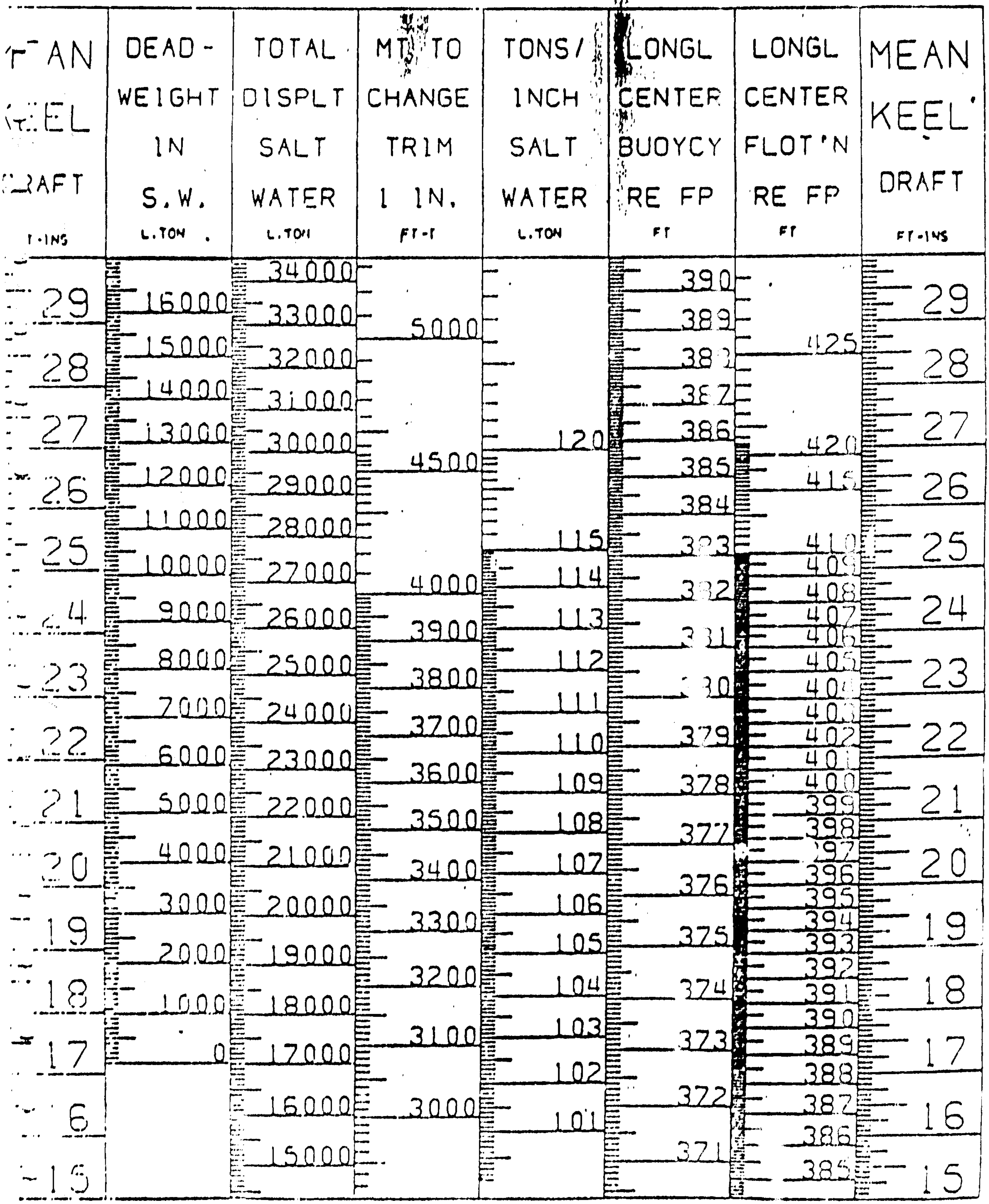
HYDROSTATIC PARTICULARS (in Salt Water S.G. 1.025)

[illegible]	Displacement (Metric Tonnes i.e. 1000 kg.)	T.P.I. (Tonnes per Inch Immersion)	M.C.T.I. (Tm. to Change Trim One Inch)	[illegible] (Metres)	[illegible] (Metres)	[illegible]	[illegible] (Metres)	[illegible] (metres)
	47,185	184.7	2274.6	120.148	119.890	3.[illegible]	20.789	455.185
	48,643	185.1	2278.9	120.139	119.794	3.763	20.453	442.550
	50,103	185,5	2238.5	120.128	119.750	3.866	20.141	432.633
	51,568	185 9	2293.7	120.117	119.706	3.970	19.851	421.399
	53,035	186.3	2303.3	120.105	119.667	4.073	19.531	411.622
	54,506	186.6	2319.0	120.092	119.616	4.177	19.329	402.546
	55,980	187.2	2331.8	120.079	119.581	4.280	19.095	394.275
	57,458	187.7	2345.8	120.066	119.552	4.384	18.877	386.621
	58,939	188.2	2360.3	120.053	119.516	4.487	18.674	379.386
	60,425	188.7	2375.1	120.039	119.476	4.591	18.484	372.558
	61,914	189.2	2392.9	120.025	119.456	4.695	18.308	366.468
	63,408	189.7	2411.0	120.011	119.430	4.799	18.143	360.720
	64,906	190.3	2429.8	119.998	119.399	4.903	17.990	355.290
	66,408	190.9	2448.9	119.934	119.362	5.007	17.848	350.164
	67,915	191.5	2468.8	119.959	119.317	5.112	17.717	345.328
	69,427	192.0	2489.[illegible]	119.954	119.266	5.216	17.595	340.770
	70,943	192.6	2507.6	119.939	119.235	5.321	17.432	336.071
	72,463	193.2	2530.3	119.924	119.158	5.425	17.373	332.204
	73,989	193.[illegible]	2554.7	119.909	119.063	5.530	17.283	328.[illegible]45
	75,520	194.6	2532.4	119.899	118.934	5.[illegible]35	17.[illegible]96	325.610
	77,057	195.4	2612.6	119.3[illegible]8	118.776	5.[illegible]	17.117	323.016
	78,600	[illegible].2	2645.2	119.845	118.595	5.[illegible]	17.0[illegible]5	320.747
	80,150	19[illegible].9	2677.3	[illegible].820	11[illegible].[illegible]37	[illegible]	[illegible]	[illegible]

GRAPH OF HYDROSTATIC DATA

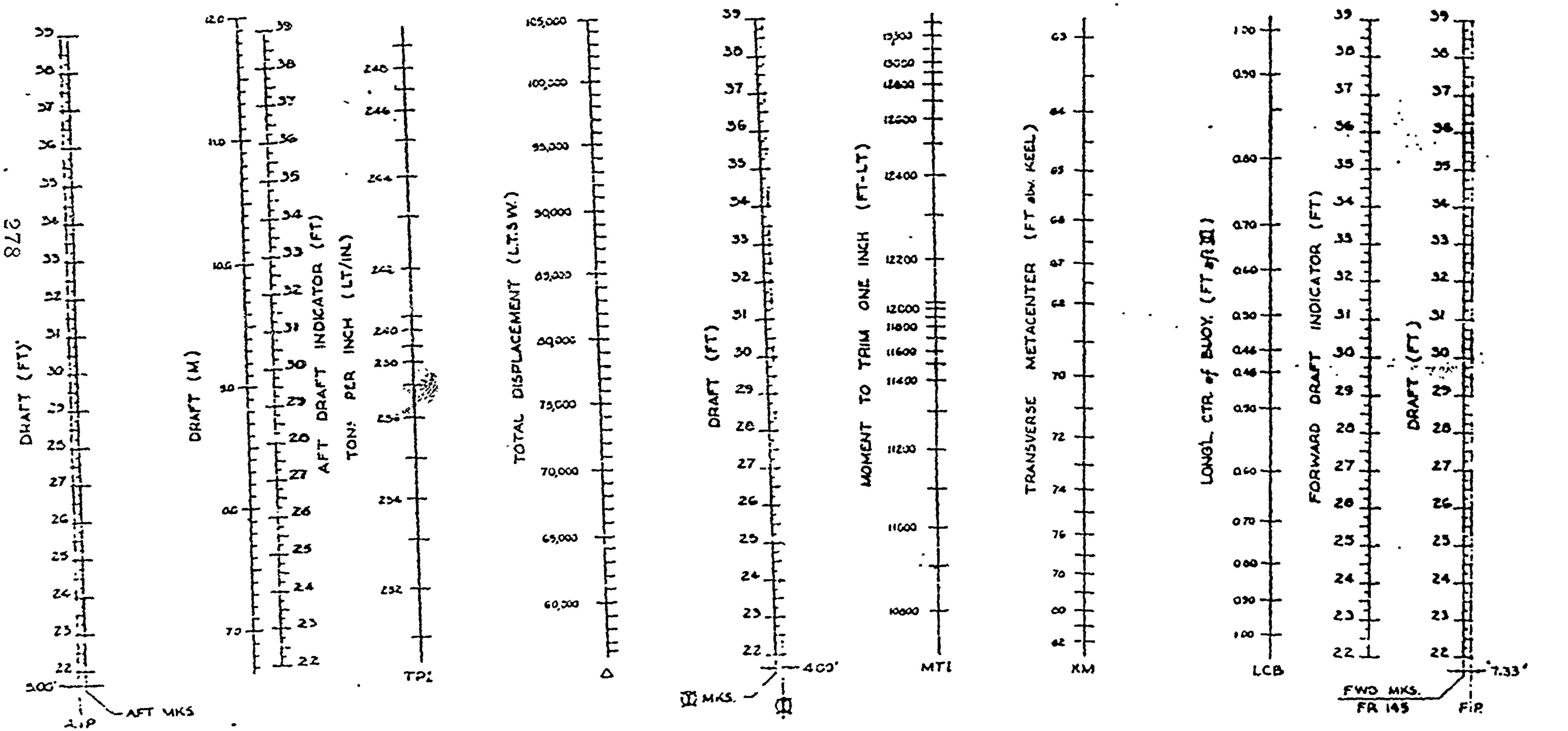


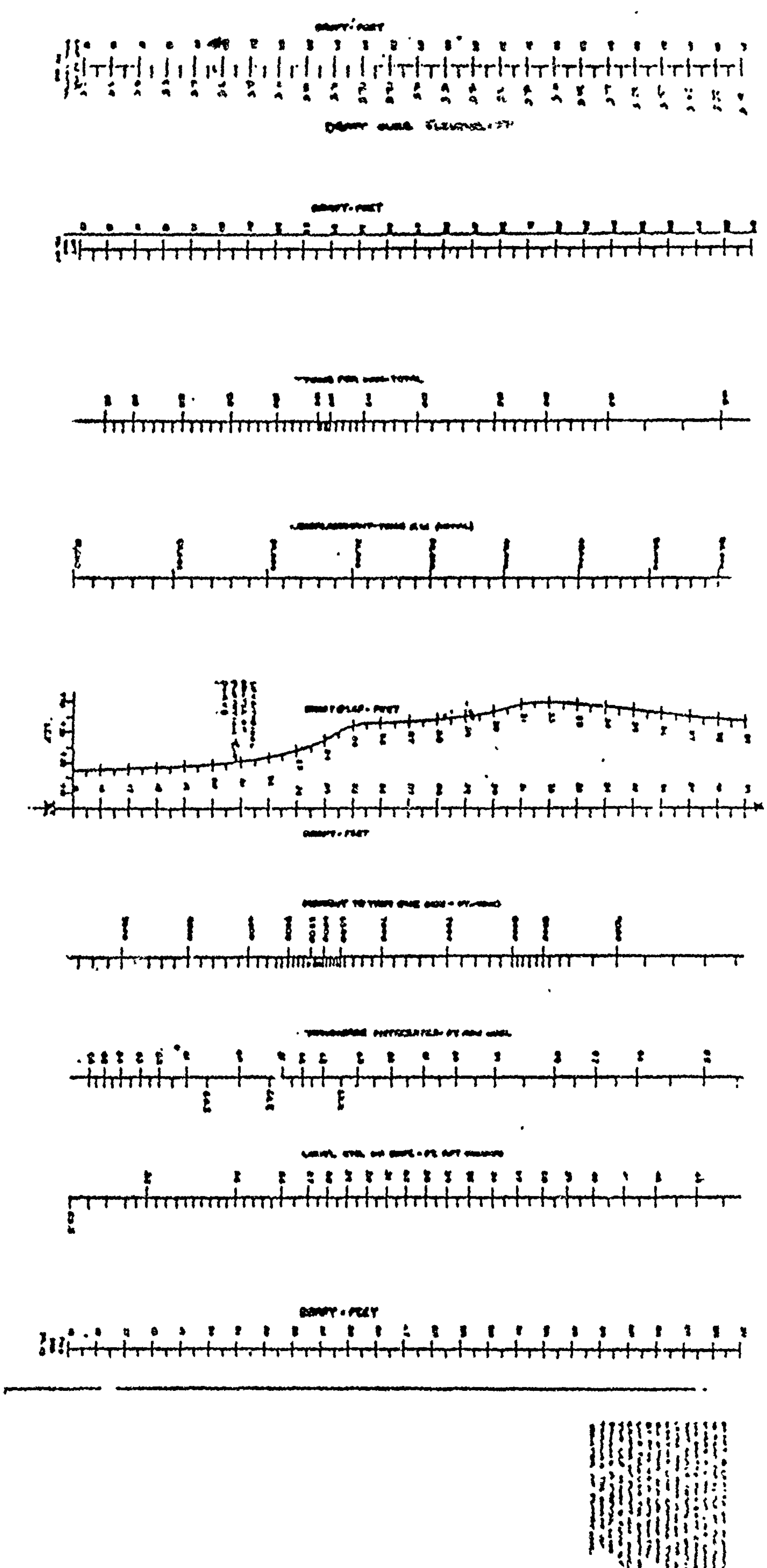
HYDROSTATIC PROPERTIES



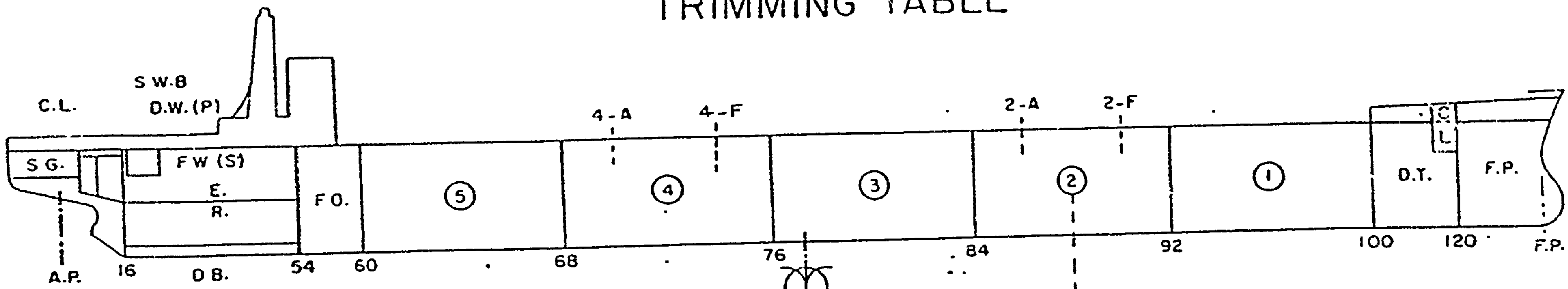
HYDROSTATICS NOMOGRAPH

INSTRUCTIONS: THE CENTER OF FLOTATION IS APPROXIMATELY AT ⊠ FOR THE DRAFT RANGE SHOWN. THEREFORE THE DRAFT AT THE LONGL CENTER OF FLOTATION IS READ DIRECTLY WHERE A STRAIGHT LINE CONNECTING THE DRAFTS AT THE FWD AND AFT MARKS CROSSES THE DRAFT ⊠ SCALE. ALL OTHER SCALES ARE READ BY PASSING A HORIZONTAL LINE THROUGH THE DRAFT AT ⊠.



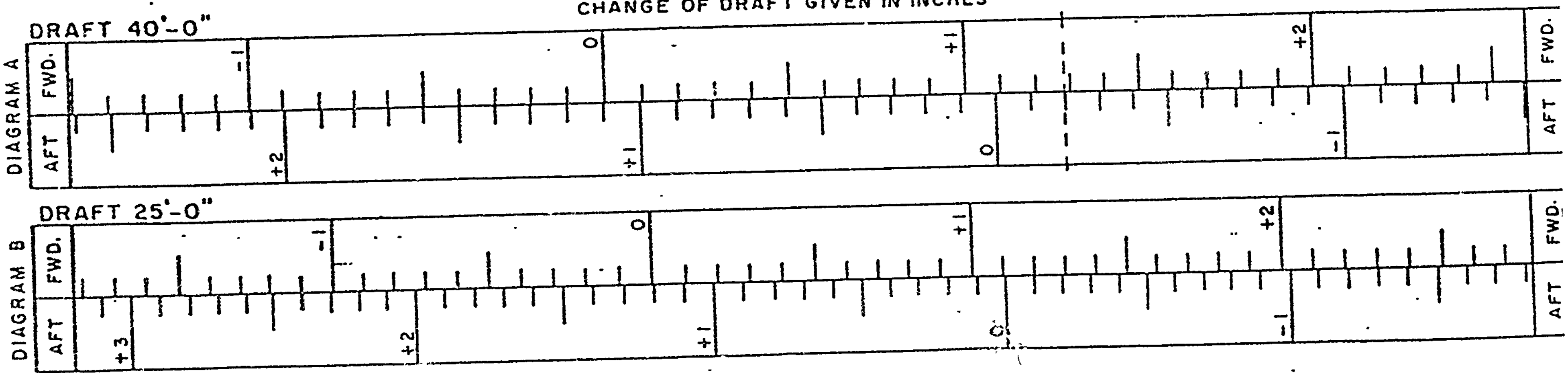

DRAFT - FEET

TRIMMING TABLE



EFFECT ON DRAFTS FOR EACH 100 TONS LOADED AT ANY LONGITUDINAL LOCATION

CHANGE OF DRAFT GIVEN IN INCHES



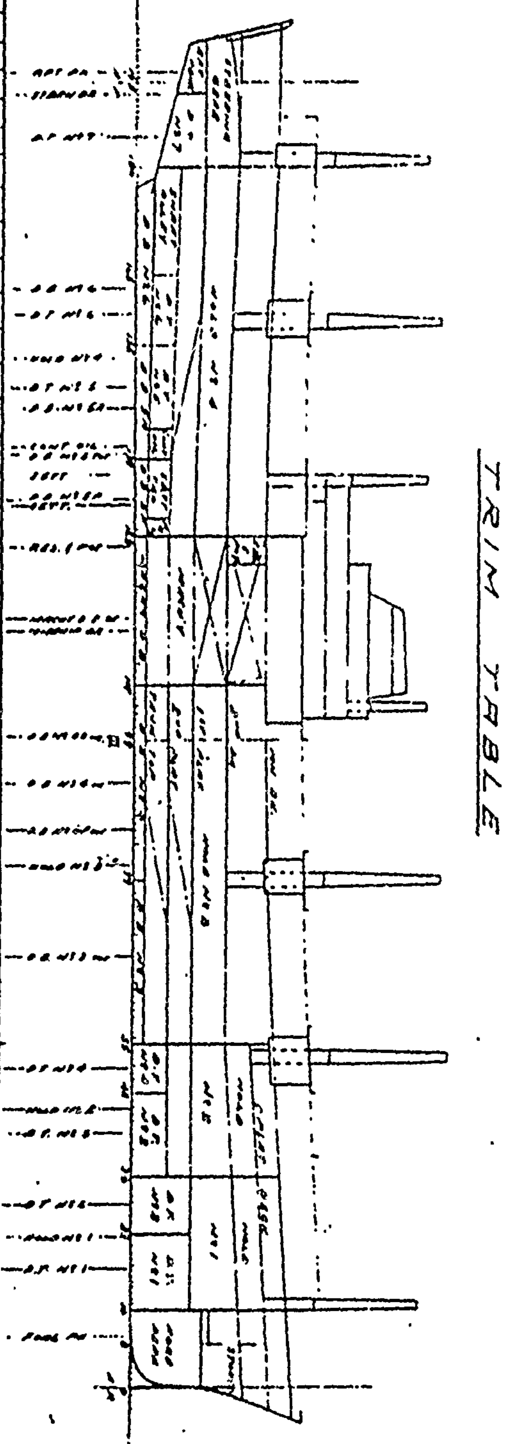
EXAMPLE: FIND CHANGE IN DRAFT AFTER LOADING 500 TONS IN NO. 2 CTR. TANK

	FORWARD	AFT
ORIGINAL DRAFTS	39'-5 5/8"	40'-1"
CORRECTION - FROM TABLE MARKED 40'-0" DRAFT DIRECTLY BENEATH THE WEIGHT 5 X (1.28") =	+ 0'-6 3/8"	5 X (-0.20") = - 0'-1"
NEW DRAFTS	40'-0"	40'-0"

NOTES: 1. THE CORRECTIONS WERE COMPUTED FOR THE TWO DRAFTS 15'-0" APART TO FACILITATE INTERPOLATION, BUT IN PRACTICE WILL BE SUFFICIENTLY ACCURATE TO REFER TO THE TABLE NEAREST THE SHIP'S DRAFT.

2 WHEN DISCHARGING, USE THE TABLE AS FOR LOADING AND CHANGE THE + AND - SIGNS.

TRIM TABLE



INITIAL EVEN KEEL DRAFT					
17'-0"		22'-0"		27'-0"	
AFT	FWD	AFT	FWD	AFT	FWD
+8.7	-6.7	+7.1	-5.5	+6.2	-4.7
+8.4	-6.3	+6.9	-5.2	+6.0	-4.5
+8.1	-5.9	+6.6	-4.8	+5.8	-4.2
+7.8	-5.6	+6.3	-4.5	+5.5	-3.9
+7.4	[illegible]	+6.[illegible]	-4.2	+5.3	-3.6
+7.1	-4.7	+5.8	-3.8	+5.0	-3.2
+6.7	-4.3	+5.5	-3.4	+4.8	-2.9
+6.3	-3.8	+5.1	-3.0	+4.5	-2.5
+5.9	-3.4	+4.8	-2.6	+4.2	-2.2
+5.5	-2.9	+4.5	-2.2	+3.9	-1.8
+5.1	-2.5	+4.2	-1.8	+3.7	-1.4
+4.7	-2.0	+3.9	-1.4	+3.4	-1.1
+4.3	-1.5	+3.5	-1.0	+3.1	-0.7
+3.9	-1.1	+3.2	-0.6	+2.8	-0.4
+3.5	-0.6	+2.9	-0.2	+2.5	+0.0
+3.2	-0.2	+2.6	+0.2	+2.3	+0.4
+2.8	+0.3	+2.3	+0.6	+2.0	+0.7
+2.4	+0.7	+1.9	+1.0	+1.7	+1.1
+2.0	+1.2	+1.6	+1.4	+1.4	+1.4
+1.6	+1.7	+1.3	+1.8	+1.2	+1.8
+1.2	+2.1	+1.0	+2.2	+0.9	+2.2
+0.8	+2.6	+0.7	+2.6	+0.6	+2.5
+0.4	+3.0	+0.4	+3.0	+0.3	+2.9
+0.0	+3.5	+0.0	+3.4	+0.1	+3.2
-0.4	+3.9	-0.3	+3.8	-0.2	+3.6
-0.7	+4.4	-0.6	+4.2	-0.5	+4.0
-1.1	+4.9	-0.9	+4.6	-0.8	+4.3
-1.5	+5.3	-1.2	+5.0	-1.1	+4.7
-1.9	+5.8	-1.6	+5.4	-1.3	+5.0
-2.3	+6.2	-1.9	+5.8	-1.6	+5.4
-2.7	+6.7	-2.2	+6.2	-1.9	+5.7
-3.1	+7.1	-2.5	+6.6	-2.2	+6.1
-3.5	+7.6	-2.8	+7.0	-2.4	+6.6
-3.9	+8.0	-3.2	+7.4	-2.7	+6.8
-4.2	+8.4	-3.4	+7.7	-3.0	+7.1
-4.6	+8.9	-3.7	+8.1	-3.2	+7.5
-4.9	+9.3	-4.0	+8.4	-3.4	+7.8
-5.2	+9.6	-4.3	+8.8	-3.7	+8.1
-5.5	+10.0	-4.5	+9.1	-3.9	+8.3
-5.8	+10.3	-4.8	+9.4	-4.1	+8.5
-6.1	+10.7	-5.0	+9.7	-4.3	+8.8

TABLE OF VARIATIONS (IN INCHES & ANG) OF FWD. & AFT DRAFT FOR EACH 100 L.T. LOADED @ ANY LONG'L LOCATION.

SAMPLE: FIND NEW DRAFTS AFTER LOADING 200T IN D.T. No 7

ORIGINAL DRAFT: FWD = 22'-3" AFT = 23'-0"

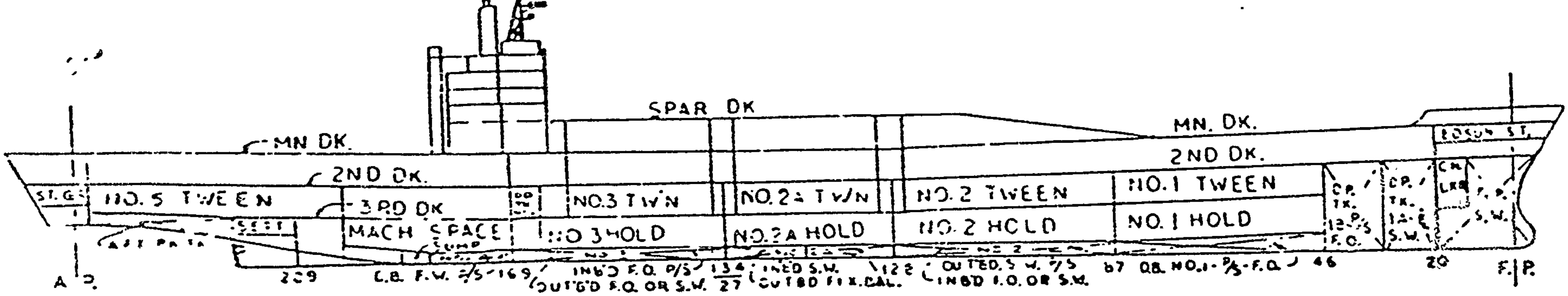
VARIATION: FROM 22-0" TABLE = -1'-9" = +12.6"

NEW DRAFT FWD = 21'-6" AFT = 24'-0.6"

NOTES: 1) THE VALUES HAVE BEEN COMPUTED FOR EVERY 5TH FRAME AND AT DRAFTS FIVE FEET APART TO FACILITATE INTERPOLATION; BUT IN PRACTICE IT WILL BE SUFFICIENTLY ACCURATE TO REFER TO THE NEAREST TABLE VALUE.

2) WHEN DISCHARGING USE THE TABLE AS FOR LOADING BUT CHANGE THE PLUS & MINUS SIGNS.

TRIM TABLE



Distance (ft)	20'-0" Draft AFT	20'-0" Draft FWD	27'-0" Draft AFT	27'-0" Draft FWD
350	-3.91	+6.93	-2.41	+5.91
	-3.63	+6.77	-2.31	+5.76
	-3.36	+6.62	-2.45	+5.61
	-3.44	+6.46	-2.31	+5.45
	-3.32	+6.31	-2.26	+5.32
300	-3.20	+6.15	-2.19	+5.20
	-3.01	+6.00	-2.11	+5.08
	-2.95	+5.85	-2.03	+4.96
	-2.83	+5.69	-1.94	+4.84
	-2.71	+5.54	-1.86	+4.72
250	-2.59	+5.39	-1.78	+4.60
	-2.47	+5.23	-1.69	+4.48
	-2.34	+5.08	-1.61	+4.36
	-2.22	+4.92	-1.52	+4.24
	-2.10	+4.77	-1.44	+4.12
200	-1.97	+4.62	-1.36	+4.00
	-1.86	+4.46	-1.27	+3.88
	-1.73	+4.31	-1.19	+3.76
	-1.61	+4.16	-1.11	+3.64
	-1.49	+4.00	-1.02	+3.51
150	-1.37	+3.85	-0.94	+3.39
	-1.25	+3.69	-0.85	+3.27
	-1.13	+3.54	-0.77	+3.15
	-1.00	+3.39	-0.69	+3.03
	-0.88	+3.23	-0.60	+2.91
100	-0.76	+3.08	-0.52	+2.79
	-0.64	+2.92	-0.44	+2.67
	-0.52	+2.77	-0.35	+2.55
	-0.40	+2.62	-0.27	+2.43
	-0.27	+2.46	-0.19	+2.31
50	-0.15	+2.31	-0.10	+2.19
	-0.03	+2.16	-0.02	+2.07
	+0.09	+2.00	+0.07	+1.95
	+0.21	+1.85	+0.15	+1.83
	+0.34	+1.69	+0.24	+1.70
⊗	+0.46	+1.54	+0.32	+1.58
	+0.58	+1.39	+0.40	+1.46
	+0.70	+1.23	+0.49	+1.34
	+0.82	+1.08	+0.57	+1.22
	+0.94	+0.93	+0.66	+1.10
50	+1.07	+0.77	+0.74	+0.98
	+1.19	+0.62	+0.82	+0.86
	+1.31	+0.46	+0.91	+0.74
	+1.43	+0.31	+0.99	+0.62
	+1.55	+0.16	+1.07	+0.50
100	+1.68	-0.00	+1.16	+0.38
	+1.80	-0.15	+1.24	+0.26
	+1.92	-0.31	+1.33	+0.14
	+2.04	-0.46	+1.41	+0.02
	+2.16	-0.61	+1.49	-0.11
150	+2.28	-0.77	+1.58	-0.23
	+2.41	-0.92	+1.66	-0.35
	+2.53	-1.07	+1.75	-0.47
	+2.65	-1.23	+1.83	-0.59
	+2.77	-1.38	+1.91	-0.71
200	+2.89	-1.54	+2.00	-0.83
	+3.01	-1.69	+2.08	-0.95
	+3.13	-1.84	+2.17	-1.07
	+3.25	-2.00	+2.25	-1.19
	+3.38	-2.15	+2.33	-1.31
250	+3.50	-2.30	+2.42	-1.43
	+3.62	-2.46	+2.50	-1.55
	+3.75	-2.61	+2.58	-1.67
	+3.87	-2.77	+2.67	-1.79
	+3.99	-2.92	+2.75	-1.91
300	+4.11	-3.07	+2.84	-2.04
	+4.23	-3.23	+2.92	-2.16
	+4.35	-3.38	+3.00	-2.28
	+4.48	-3.53	+3.09	-2.40
	+4.60	-3.69	+3.17	-2.52
350	+4.72	-3.84	+3.25	-2.64
	+4.84	-4.00	+3.34	-2.76
	+4.96	-4.15	+3.42	-2.88

NOTE:
The above Trim Table indicates draft corrections in inches at fwd and aft draft marks when a weight of 100 tons is loaded at a given distance from midship.

When discharging weights, use table as in loading with plus and minus signs reversed.

EXAMPLE:
Find new drafts after loading 100 tons in No. 1 hold (210'-0" fwd of amidship):

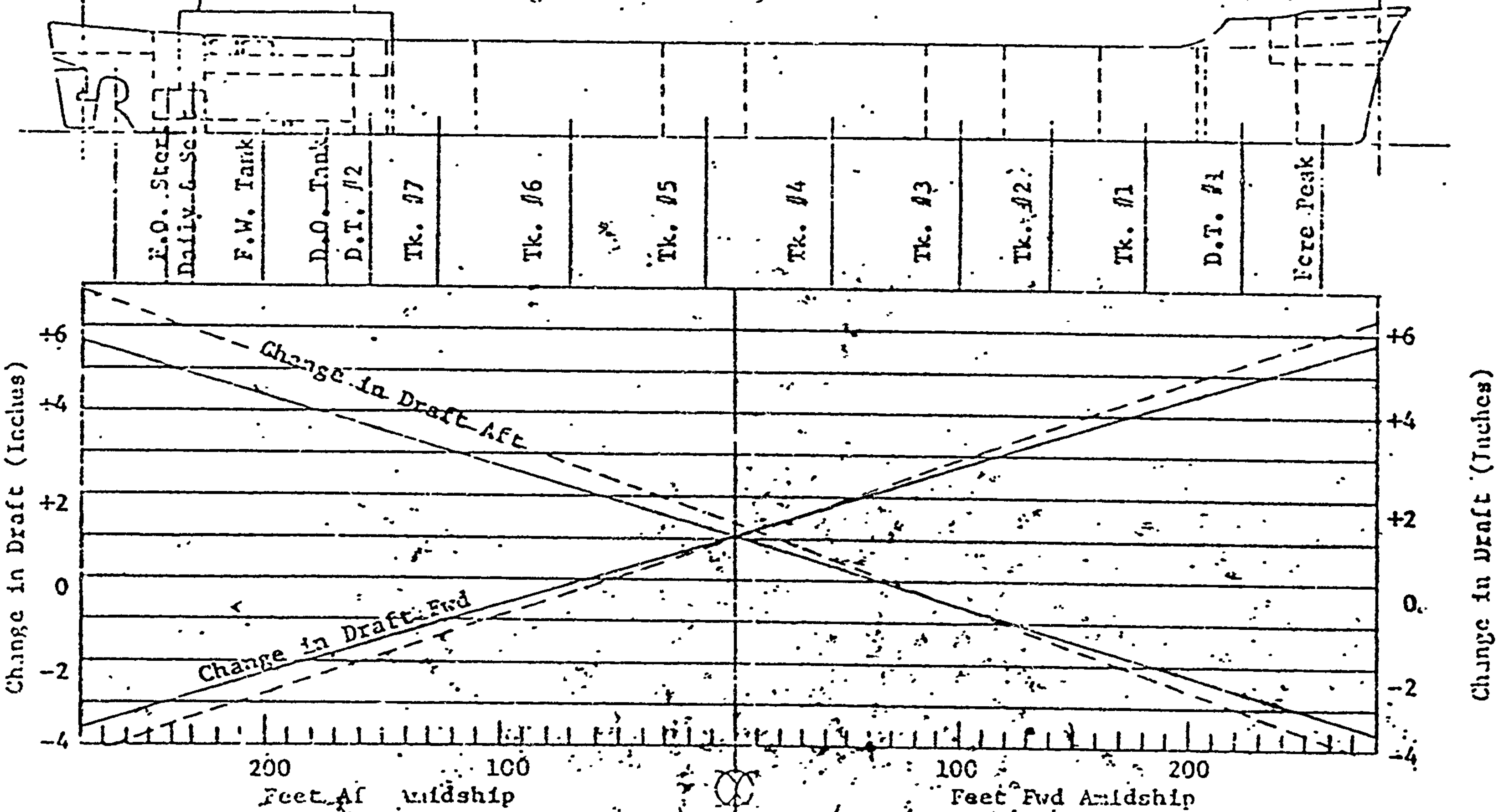
	Fwd		Aft
Initial Drafts	21'-4"		25'-8"
	+ 0'-4.31"		- 0'-1.67"
	21' 8-3/8"		25' 6-3/8"

CORRECTION:
(Interpolated between tables for a mean draft of 23'-5")

New Drafts (To Nearest 1/8")

Trimming Diagram

The diagram illustrates the effect on the draft at the perpendiculars of adding 100 tons at any location in this ship. If weights are removed, the signs on the change of draft scales should be reversed.



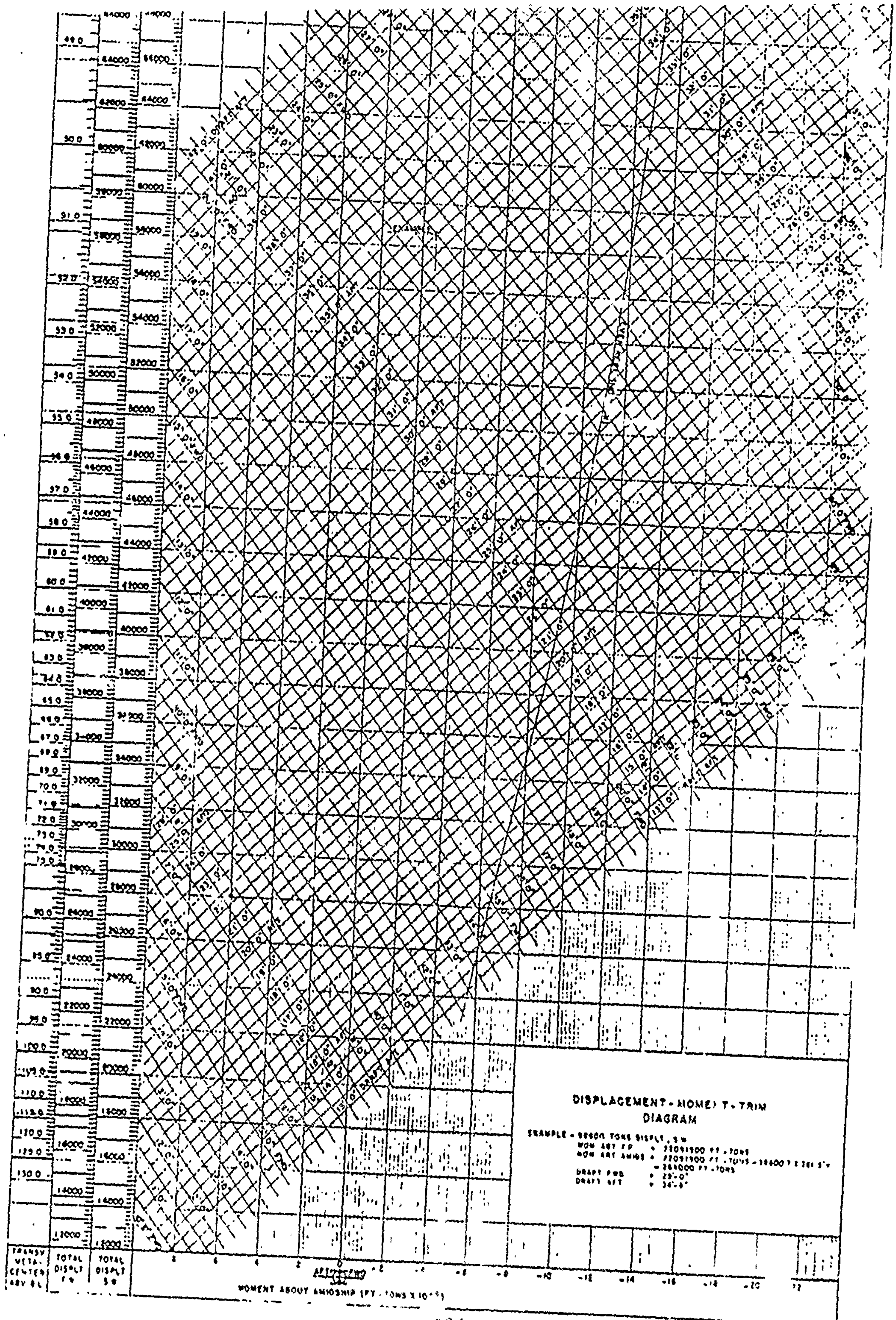
Full Lines Indicate Properties of 32'-0" W.L.

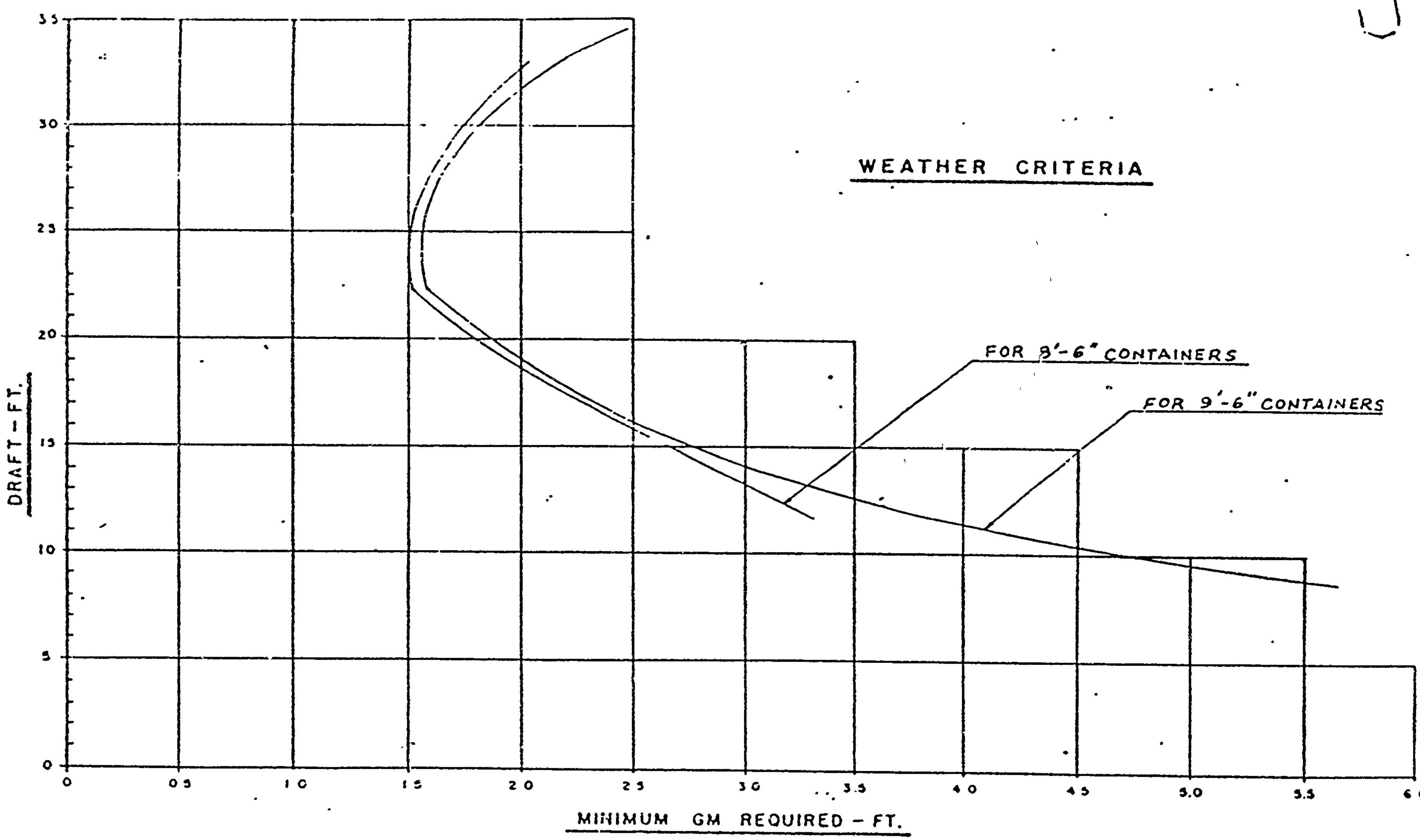
Dashed Lines Indicate Properties of 24'-0" W.L.

Example: 150 Tons added in Tank No. 2 with Ship at 24'-0" Draft

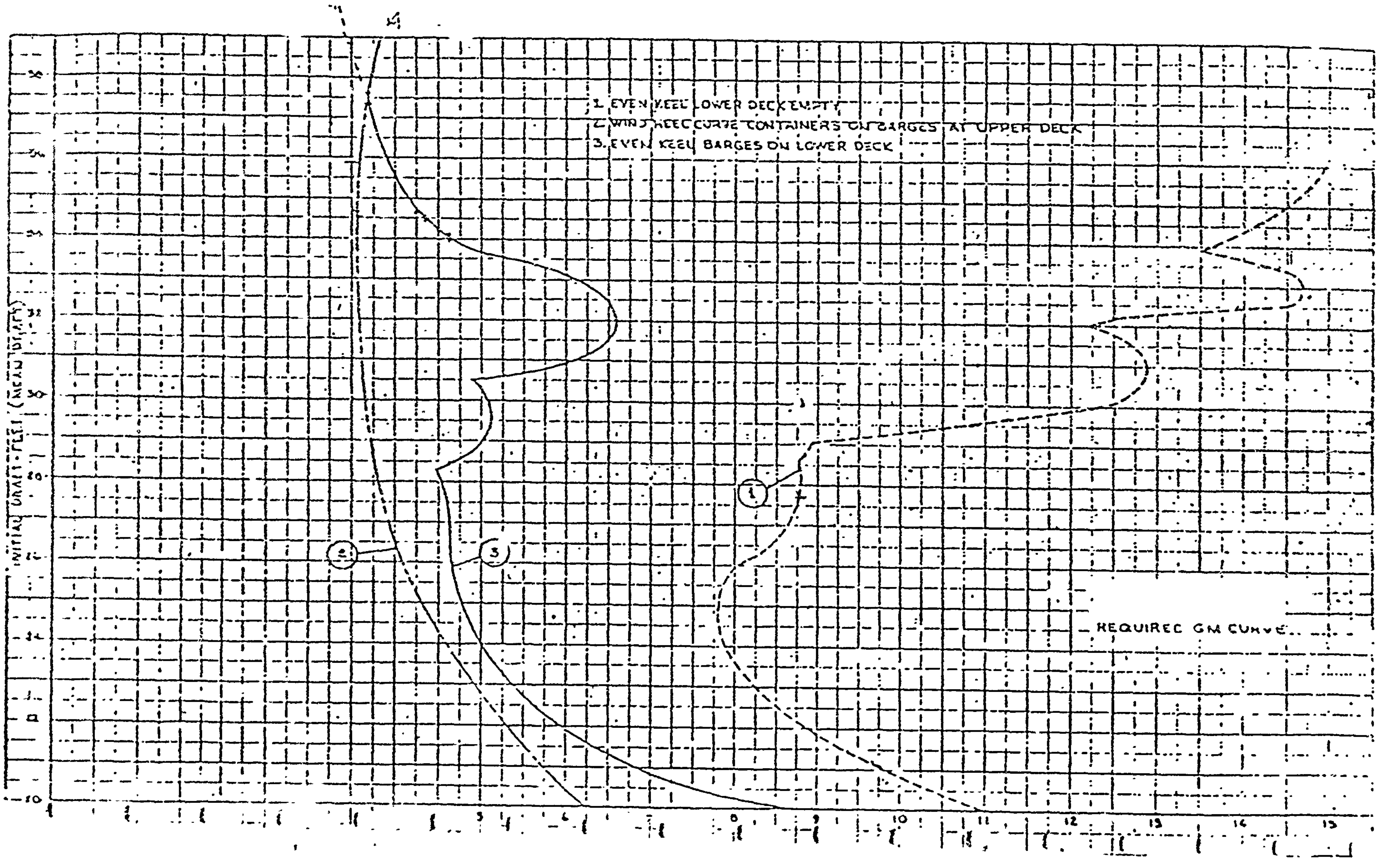
Change in Draft Fwd = 1.5 x (+3.65) = 5.48"

Change in Draft Aft = 1.5 x (-1.40) = 2.10"

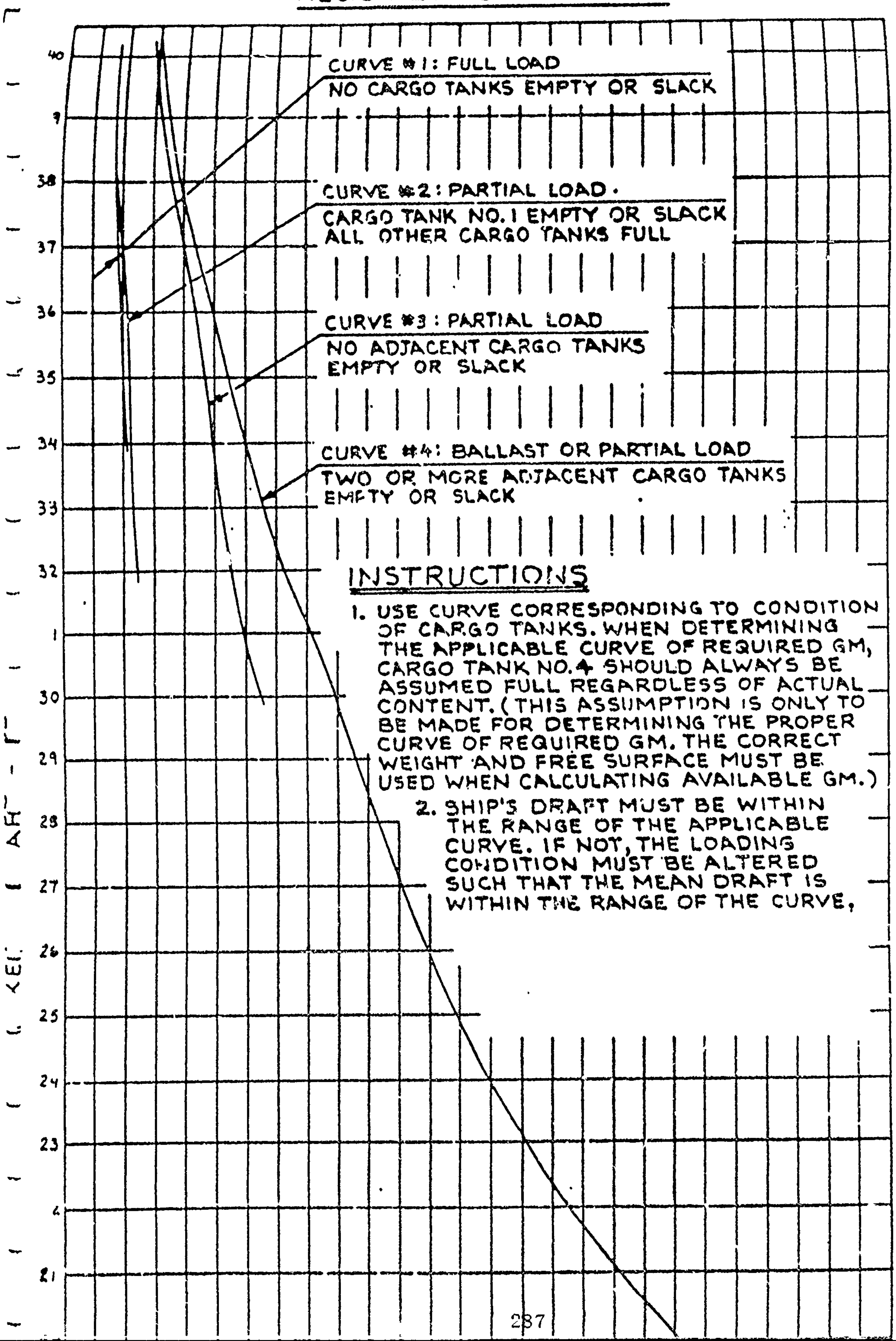

DISPLACEMENT-MOMENT-TRIM
DIAGRAM
TRANSV META-CENTER ABV BL
TOTAL DISPL'T F W
TOTAL DISPL'T S W
MOMENT ABOUT AMIDSHIP



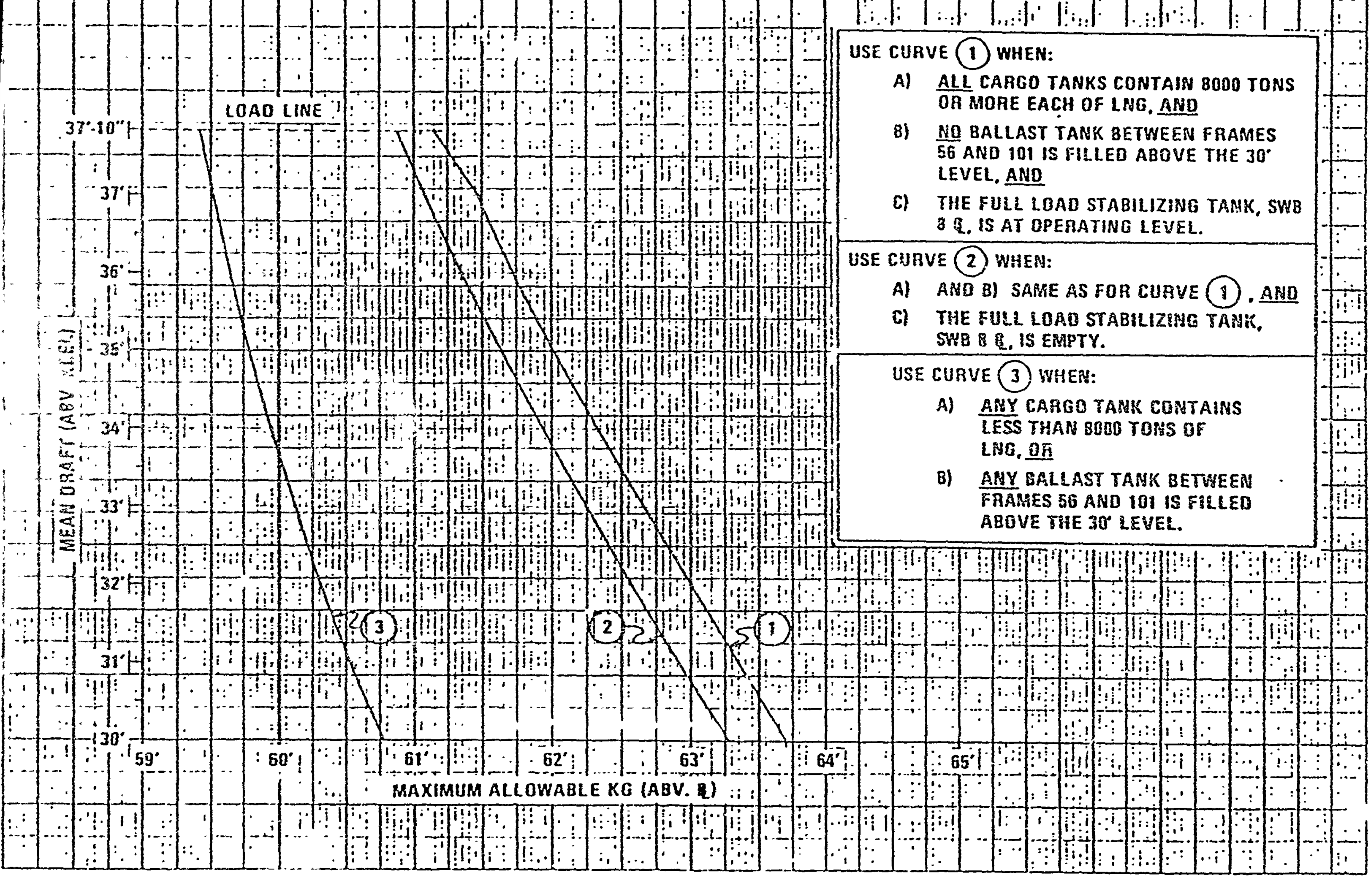
NOTE: MINIMUM GM REQUIREMENT HAS BEEN PREPARED FOR 1) 9'-6" CONTAINERS ON DECK STACKED 4 HIGH
2) 8'-6" CONTAINERS ON DECK STACKED 4 HIGH


1. EVEN KEEL LOWER DECK EMPTY
2. WIND HEEL CURVE CONTAINERS ON BARGES AT UPPER DECK
3. EVEN KEEL BARGES ON LOWER DECK
REQUIRED GM CURVE
INITIAL DRAFT - FEET (MEAN DRAFT)

REQUIRED GM CURVES



MAXIMUM ALLOWABLE KG (CORRECTED FOR FREE SURFACE)



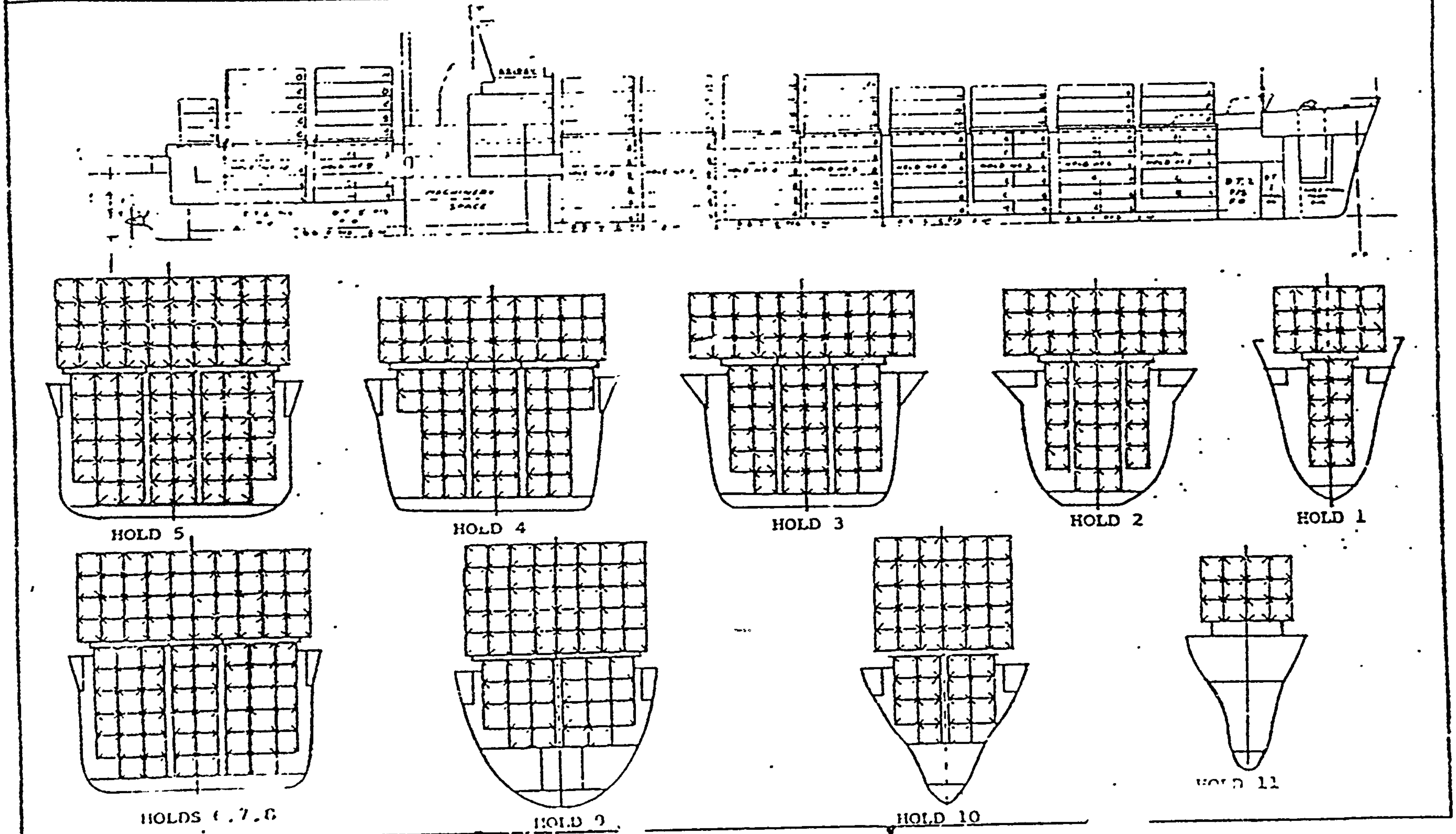
SUMMARY of CAPACITIES & CENTERS

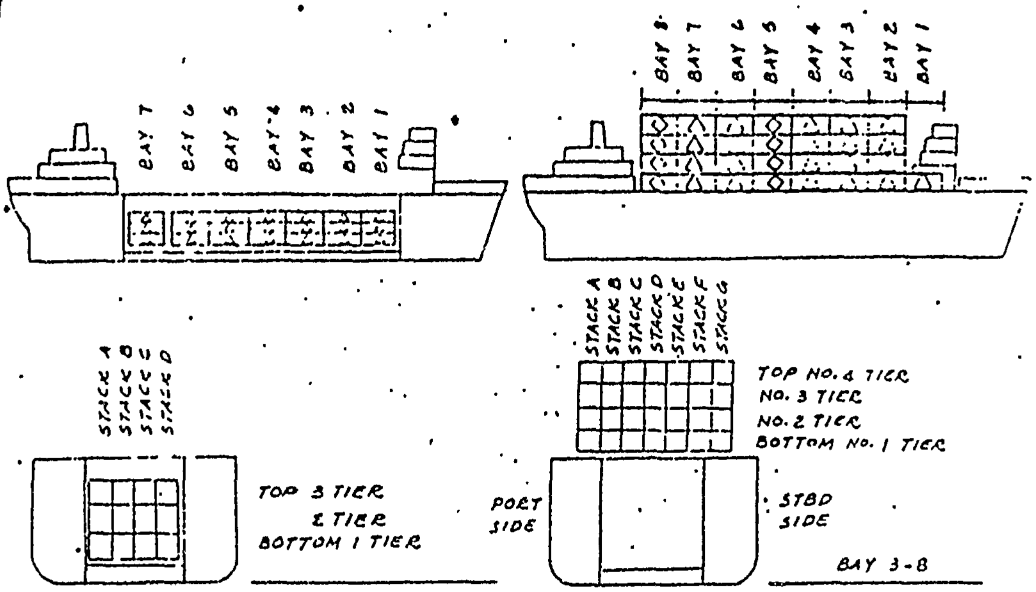
CARGO SPACE		BTWN. FRAMES	BALE CARGO CU. FT.	VCG ABOVE B.L. FT.	LCG AFT F.P. FT.	DESIGNED DECK LOAD LB/SQ FT	CLEAR DECK AREA SQ. FT	CLEAR DECK HEIGHT FT & INS	MINIMUM [illegible] FT	LCG [illegible] FT
No. 1	MAIN DECK	14-36	-	-	-	360	2645	-	56.60	53.6
	PLAT. DECK	14-36	19218	52.33	53.6	380	2283	6'-11"	46.20	56.0
	2ND DECK	14-36	17240	43.18	53.3	430	1727	7'-7¼"	38.78	56.2
	1ST PLAT.	14-36	19292	30.55	54.2	[illegible]	1617	15'-2½"	22.25	57.2
TOTAL No. 1		14-36	55750	41.95	53.7	-	7672	-	46.50	54.3
No. 2	MAIN DECK	36-55	-	-	-	360	3000	13'-6½"	53.99	96.6
	PLAT. DECK	36-55	25628	49.65	98.5	390	3130	6'-11"	45.44	98.9
	2ND DECK	36-55	25085	40.33	99.2	430	2773	7'-7¼"	35.95	99.3
	1ST PLAT.	36-55	31167	28.80	99.2	620	2282	10'-6"	22.25	100.4
	2ND PLAT.	36-55	16823	17.29	100.9	[illegible]	2059	6'-4½"	13.25	100.7
TOTAL No. 2		36-55	98703	35.18	99.3	-	13242	-	36.39	99.0
No. 3	MAIN DECK	55-107	-	-	-	360	8848	13'-6½"	50.81	188.3
	2ND DECK	55-107	147246	42.65	183.8	[illegible]	9288	12'-8¼"	34.50	188.4
	1ST PLAT.	55-107	96399	27.72	188.9	560	8737	10'-5¼"	22.25	189.0
	2ND PLAT.	55-107	64344	17.06	189.8	400	7463	6'-11½"	13.25	190.3
	TANK TOP	55-107	59256	8.54	191.0	[illegible]	7452	6'-8½"	4.83	192.6
TOTAL No. 3		55-107	367245	28.74	187.4	-	41805	-	26.25	189.0
No. 4	MAIN DECK	128-180	-	-	-	360	8489	13'-6½"	50.43	373.8
	2ND DECK	128-180	136720	43.46	369.9	460	9360	12'-5¼"	37.80	368.5
	1ST PLAT.	128-180	89285	29.29	363.0	560	8246	10'-2¼"	24.12	365.9
	2ND PLAT.	128-180	56214	18.67	362.1	1520	6755	6'-4½"	15.12	360.6
TOTAL No. 4		128-180	281219	34.01	367.7	-	32850	-	32.40	367.6
TOTAL EXCLUDING DRIVEWAYS			802917	32.29	230.4	-	95579	-	31.31	229.1
STERN DRIVEWAY ℄		180-TRANS	11869	45.18	461.0	560	845	12'-6"	38.15	459.5
MIDSHIP DRIVEWAY STBD		108-125	14816	56.00	271.5	360	1125	12'-1½"	49.50	271.5
GRAND TOTAL CARGO SPACES			829602	32.90	234.5	-	97550	-	31.58	229.6

TANKS	BTWN. FRAMES	CAPACITY 100%	CAPACITY 98%	L. TONS FUEL OIL [illegible] 98%	L. TONS S.W. 35 CU FT/TON 100%	L. TONS F.W. 36 CU FT/TON 100%	VCG ABV. B.L. FT	LCG AFT F.P. FT	MAX. FREE SURFACE MOMENT [illegible]
FUEL OIL:		BBLS.	BBLS.						40/37.88
SETTLER FWD	130-134	373.9	366	54.7	-	-	9.30	316.3	289
SETTLER AFT	134-139	377.8	370	55.3	-	-	9.55	327.1	289
CONTAM. F.O.	139-148	355.4	348	52.0	-	-	9.77	337.5	268
TOTAL FUEL OIL TKS.		1106.9	1084	162.0	-	-	9.54	32[illegible].8	846
DEEP TANKS:		CU. FT	BBLS.						40/35.0
No. 1 CNTR.	14-27	9093	~	-	260.1	252.9	12.29	42.9	476
2 CNTR.	27-36	11565	~	-	330.5	321.3	12.21	65.5	1627
3 CNTR	36-40	13704	~	-	391.5	380.6	7.25	91.0	5367
4 P&S	41-55	10183	1778	265.4	291.2	283.1	7.20	114.0	1627
5 CNTR	141-155	6150	1073	160.2	175.7	170.8	10.25	357.5	868
6 CNTR	155-165	3952	690	102.9	112.9	109.8	10.85	383.5	333
7 P&S	180-193	8922	~	-	254.8	247.9	20.57	446.2	1290
TOTAL DEEP TANKS		63574	3541	528.5	1816.7	1766.2	11.25	177.0	11592
DOUBLE BOTTOMS:		CU. FT.	BBLS.						40/35.0
No. 3 INBD P&S	55-79	8184	1428	213.0	233.6	227.1	2.45	152.9	126
3 OUTBD P&S	55-79	6226	1087	162.3	178.0	173.1	2.80	156.9	[illegible]
SUB. TOT No. 3	55-79	14410	2515	375.2	411.6	400.2	2.60	154.6	2107
No. 4 INBD P&S	79-107	9758	1703	254.4	279.0	271.2	2.47	217.2	1149
4 FWD OUTBD P&S	79-93	5734	1001	149.4	163.8	159.2	2.74	200.5	1679
4 AFT OUTBD P&S	93-107	6170	1077	160.6	176.0	171.1	2.72	234.6	2036
SUB. TOT. No. 4	79-107	21662	3781	564.4	618.8	601.5	2.61	217.7	4858
MACH'Y INBD P&S	107-128	6863	1198	178.8	196.2	190.7	2.49	277.1	897
OUTBD P&S	107-128	7092	1238	184.6	202.4	196.8	2.[illegible]	274.7	2014
SUB. TOT. MACH'Y	107-128	13955	2436	363.4	398.6	387.[illegible]	2.[illegible]	275.9	2911
No. 5 SF CNTR	128-139	4020	702	104.7	[illegible]	111.6	2.55	314.8	1712
5F OUTBD P&S	128-139	2521	440	65.8	72.0	70.0	3.54	311.1	499
5A P&S	139-155	6520	1138	169.8	186.2	181.0	3.27	350.6	2510
SUB. TOT No. 5	128-155	13061	2280	340.3	373.0	362.6	3.11	334.8	4801
No. 6 CNTR	155-180	3171	553	82.6	90.5	88.0	4.08	392.3	1412
TOTAL DOUBLE BOTTOMS		66259	11565	1725.9	1892.5	1839.5	2.79	247.6	[illegible]
PEAK TANKS:		CU. FT.							40/35.0
FOREPEAK	0-14	3480	-	-	99.4	96.6	15.00	18.2	32
AFT PEAK	193-TRANS	2128	-	-	60.8	59.1	22.69	469.2	848
TOTAL PEAK TKS	-	5608	-	-	160.2	155.7	17.92	187.3	880
FEED & POT. WATER		CU. FT.							40/36.0
RES. FEED INBD P&S	123-128	2307	-	-	-	64.0	40.44	301.[illegible]	102
POT. W. INBD P&S	125-128	1131	-	-	-	31.4	42.00	301.1	6

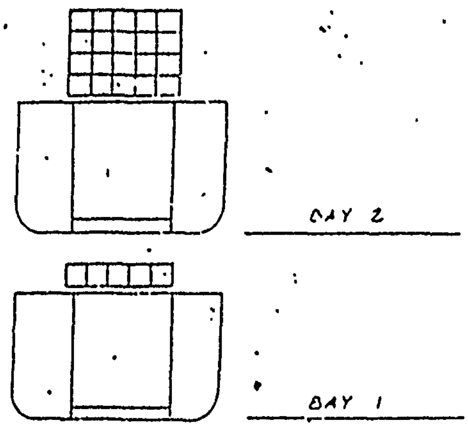
NOTE: FOR OIL TANKS CARRIED 98% FULL, USE THE REDUCED FREE SURFACE VALUE FOR SUCH TANKS, EXCEPT WHERE SPECIFICALLY INSTRUCTED OTHERWISE.

VESSEL	CONTAINER CARGO CAPACITY DATA	





CARGO STOWAGE		
CARGO.	REFRIGERATED CONTAINER ◇	DRY CARGO CONTAINER △
	40'-8'-8'-6"/9'-6"	40'-8'-8'-6"/9'-6"
UPPER DECK	56	137
HOLD	—	84
QUANTITY TOTAL	56	221



CONTAINER	TIER	NO OF CONTAINERS	V.C.G. ABOVE BASELINE	
			8'-6" HIGH CONTAINER	9'-6" HIGH CONTAINER
UPPER DECK	4	47	72.5	76.0
	3	47	64.0	66.5
	2	47	5[illegible].5	57.0
	1	52	47.0	47.5
SUB TOTAL		173		
HOLD	3	28	27.94	30.44
	2	28	17.44	20.94
	1	28	10.94	11.44
SUB TOTAL		84		

CONTAINER	BAY	NO OF CONTAINERS	LCG FROM AP FOR 8'-6" [illegible] CONTAINER
UPPER DECK	1	5	43[illegible].0
	2	20	3[illegible]3.0
	3	28	3[illegible]6.7
	4	28	305.1
	5	28	[illegible]
	6	28	215.6
	7	28	173.6
	8	28	132.1
SUB TOTAL		193	
HOLD	1	12	401.7
	2	12	360.5
	3	12	319.3
	4	12	272.9
	5	12	2[illegible]4.1
	6	12	185.1
	7	12	146.6
SUB TOTAL		84	

	(* = EPOXY COATED) TANK	FRAME	100% VOL. GALS.	100% CAP. L.TONS	VCG (KEEL BOT) @100%	LCG (⊗) A+/F-	SLACK FR.SURF. FT-TONS	98%-5° FR.SURF. FT-TONS
SALT WATER BALLAST	FOREPEAK	C-22	176699	674.94	37.01	-342.27	4187	—
	#1 P *	28-34	151343	578.09	19.16	-251.96	2459	—
	#1 S *	28-34	152006	580.62	19.12	-251.96	2459	—
	#2 ℄ *	34-40	338363	1292.45	17.07	-206.51	6504	—
	#2 P	34-40	106147	405.45	31.91	-203.69	618	.
	#2 S	34-40	105525	403.07	32.03	-203.79	618	—
	#3 P *	40-46	205978	786.78	29.54	-156.87	1702	—
	#3 S *	40-46	205075	783.33	29.63	-156.74	1702	—
	#4 P	46-52	183850	702.25	22.97	-108.84	757	—
	#4 S	46-52	182947	698.80	23.04	-108.82	757	—
	#5 P	52-58	383469	1464.74	25.09	-60.70	3848	—
	#5 S	52-58	381440	1456.99	25.17	-60.75	3868	—
	#6 P *	58-64	443627	1694.53	23.81	-12.25	4155	—
	#6 S *	58-64	440875	1684.01	23.82	-12.30	4155	—
	#7 P	64-67	236711	904.17	23.39	+23.88	2162	—
	#7 S	64-67	236711	904.17	23.39	+23.88	2162	—
	#8 ℄	84-88	230910	882.01	19.73	+190.21	4534	—
	#8 P *	84-88	434945	1661.36	26.60	+181.77	4372	—
	#8 S *	84-88	433138	1654.46	26.68	+181.75	4372	—
	#9 ℄	88-94	306274	1169.95	22.03	+230.14	6801	—
	#9 P	88-94	416459	1590.75	33.06	+230.98	4372	—
	#9 S	88-94	414653	1583.85	33.16	+231.00	4372	—
	#10 P *	94-99	303692	1160.02	38.19	+274.96	3643	—
	#10 S *	94-99	301642	1152.18	38.30	+275.07	13643	—
	#11 P *	99-107	339829	1298.05	41.90	+323.55	5694	—
	#11 S *	99-107	335937	1283.18	42.12	+323.83	5694	—
	#12 P	109-125	293213	1119.99	40.97	+420.82	414	—
	#12 S	109-125	293213	1119.99	40.97	+420.82	414	—
			(98%)	(98%)	(@98%)			
FUEL OIL	#3 ℄	40-46	391330	1405.23	15.78	-158.70	6399	3846
	#4 ℄	46-52	417377	1498.76	15.34	-110.05	6399	3846
	#5 ℄	52-58	427837	1536.33	15.42	-61.48	6399	3846
	#6 ℄	58-64	433697	1557.37	15.65	-12.74	6399	3846
	OVERFLOW P	76-81	37321	134.02	3.43	+128.19	1954	353
	SLUDGE ℄	76-79	37112	133.27	3.00	+121.10	3200	498
			(100%)	(100%)	(@100%)			
FRESH WAT.	POT.WAT. ℄	64-67	97947	367.41	17.08	-23.92	1507	--
	RES.FEED P	70-75	35183	130.66	3.10	+80.69	687	—
	RES.FEED S	70-75	35183	130.66	3.10.	+80.69	687	—
	DISTILLED P	50-52	18406	68.35	44.15	+149.87	26	—
	SEWAGE P/S	46-52	129362	494.12	22.07	-108.94	274	—
			(OP LVL.)	(OP. LVL.)	(@OP. LVL.)			
	ROLL STAB.	67-70	221256	773.65	12.58	+47.64	60170	—

COMPARTMENT CAPACITIES

TANK	CAP L.TONS	WEIGHT L.TONS	VCG ABOVE ℄ (FEET)	VERT MOMENT (FT-TONS)	LCG FROM FP (FEET)	LONGL MOMENT (FT-TONS)	VERT. MOM. OF F.S. FT.TONS SLACK	VERT. MOM. OF F.S. FT.TONS 98% FULL
S. W. BALLAST TANKS								
No.1 Double Bottom P	168.3		2.7		131.9		1599	
No.1 Double Bottom S	168.3		2.7		131.9		1599	
No.2 Double Bottom CL	459.1		2.4		204.1		11568	
No.2 Double Bottom P	147.7		2.7		209.6		865	
No.2 Double Bottom S	147.7		2.7		209.6		865	
No.3 Double Bottom CL	472.7		2.5		303.0		12478	
No.3 Double Bottom P	239.6		2.6		304.3		2083	
No.3 Double Bottom S	239.6		2.6		304.3		2083	
No.4 Double Bottom CL	483.0		2.5		394.0		12481	
No.4 Double Bottom P	223.3		2.6		391.1		1809	
No.4 Double Bottom S	223.3		2.6		391.1		1809	
No.5 Double Bottom P	100.2		2.7		543.0		639	
No.5 Double Bottom S	100.2		2.7		543.0		639	
M1 Double Bottom P	108.0		2.7		480.9		780	
M1 Double Bottom S	108.0		2.7		480.9		780	
Fore Peak	259.4		29.4		28.7		304	
Aft Peak	252.4		30.5		645.6		3092	
Total	3900.8							
FUEL OIL TANKS								
No.1 Deep Tank (D.O.)	138.3		18.0		48.3		163	153
No.2 Deep Tank P	182.4		18.3		66.8		110	103
No.2 Deep Tank S	182.4		18.3		66.8		110	103
No.3 Wing Tank P	296.3		26.0		103.8		326	2[illegible]0
No.3 Wing Tank S	296.3		26.0		103.8		326	280
No.4 Wing Tank P	346.8		20.3		149.1		1094	563
No.4 Wing Tank S	346.8		20.3		149.1		1094	563
No.5 Deep Tank P	363.0		13.4		544.3		1656	820
No.5 Deep Tank S	325.6		13.2		544.1		1359	700
No.6 Deep Tank P	125.6		10.0		592.5		138	112
No.6 Deep Tank S	100.3		11.1		588.4		119	91
MA Settlers Outbd. P	183.0		16.7		446.7		224	
MB Settlers Outbd. S	183.0		16.7		446.7		224	
MC Settlers Inbd. P	193.9		15.9		446.8		224	
MD Settlers Inbd. S	192.9		15.9		446.8		224	
Total	[illegible]		293					

BALLAST WING TANKS – V.C.G. and FREE SURFACE DATA

1 - PORT OR STBD			
TONS	V.C.G.	FREE SURF.	NOTES
100	7.3'	200	
200	10.7'	530	
300	13.4'	940	
400	15.6'	1380	
500	17.6'	1980	
560	19.0'	2459	
580	19.1'	0	

2 - PORT OR STBD			
TONS	V.C.G.	FREE SURF.	NOTES
100	19.0'	190	
200	22.5'	525	
250	24.2'	334	
300	26.6'	50	
405	31.9'	0	

5 - PORT OR STBD			
TONS	V.C.G.	FREE SURF.	NOTES
100	3.0'	670	
200	5.5'	1100	
300	7.5'	1560	
400	9.0'	2000	
500	10.9'	2400	
600	12.0'	2700	
700	13.5'	2980	
800	14.8'	3220	
900	16.0'	3470	
1000	17.6'	3750	
1125	19.5'	2086	
1300	22.2'	305	
1460	25.1'	0	

6 - PORT OR STBD			
TONS	V.C.G.	FREE SURF.	NOTES
200	4.0'	1900	
300	5.3'	2350	
400	6.6'	2700	
500	8.5'	3130	
600	9.2'	3310	
700	10.5'	3530	
800	11.8'	3700	
900	12.8'	3840	
1000	14.0'	3930	
1100	15.4'	4040	
1340	19.0'	2257	
1400	21.0'	360	
1689	23.8'	0	

GAIN I[illegible] M BY BALLASTING TANKS

GAIN IN GM BALLASTING TANKS, FEET			
DISPLACEMENT LONG TONS	NO 4 AFT D.B. TANK	FORWARD D.TK. P & S	FORWARD PEAK TANK
	61.00	188.76	403.11
20,000	+0.07	+0.47	+0.27
18,000	+0.07	+0.50	+0.27
16,000	+0.07	+0.37	+0.2[illegible]
14,000	+0.09	+0.33	+0.20
12,000	+0.09	+0.20	+0.13
10,000	+0.16	+0.03	+0.08

NOTE: 1. FOR DIFFERENT DISPLACEMENTS THAN SHOWN, INTERPOLATE BETWEEN VALUES GIVEN.
2. WHEN DEBALLASTING USE THE TABLE AS FOR BALLASTING AND CHANGE THE + AND − SIGNS.

TABLE OF GM GAIN VS. DISPLACEMENT FOR BALLAST TANKS

VCG	TANK	S.W. CAP'Y. 100% (L.T.)	INITIAL DISPLACEMENT (GM GAIN IN FT.) LONG TONS IN S.W. 18,000	20,000	22,000	24,000	26,000	28,000	30,000	32,000
22.5	Forepeak	429.4	.183	220	.247	.275	.260	.190	.209	.213
31.4	D.T. 1A	574.	-.031	.053	.127	.154	.157	.072	.107	.127
31.4	D.T. 1B-PS	271.9	-.014	.094	.185	.246	.259	.134	.169	.202
4.0	D.B. 21-PS	320.8	1.367	1.164	1.140	1.106	1.055	.896	.874	.855
4.9	D.B. 20-PS	535.4	.725	.738	.743	.730	.681	.569	.563	.555
3.9	D.B. 2A1-PS	721.	1.042	1.020	1.012	.992	.931	.791	.777	.755
4.5	D.B. 30-PS	739.8	1.034	1.020	1.011	1.000	.938	.800	.783	.761
18.6	S.T. Aft PS	645.	.396	.472	.477	.511	.487	.379	.383	.395
28.4	Aft Peak ℄	835.9	.103	.200	.279	.316	.315	.207	.229	.250
31.6	Aft Peak PS	245.6	-.042	.043	.038	.068	.071	.034	.038	.053
14.5	SternTubeCompt.	202.1	.155	.216	.188	.207	.190	.155	.142	.151

NOTE: These values are computed from and intended primarily for conditions where calculated available GM approaches the limits defined by the Required GM Curve (page 15), and are <u>not</u> intended to preclude the remainder of the complete stability calculation. They are intended <u>only</u> for the convenience of the Master in ascertaining the relative advantages of the ballast tankage available to him.

NET EFFECT ON KG BY BALLASTING TANKS (IN FEET)

SWB No. 1

LVL (FT)	DRAFT 30 FT	36 FT	Notes
12	-0.02	-0.02	
24	-0.07	-0.05	
36	-0.10	-0.07	
48	-0.08	-0.05	
62.29	+0.01	+0.04	
62.29	-0.44	-0.33	Pressed Up

SWB No. 2 P&S

LVL (FT)	DRAFT 30 FT	36 FT	Notes
2	-0.03	-0.02	
6.3	-0.25	-0.19	Innerbottom
10	-0.45	-0.36	
20	-0.83	-0.65	
30	-1.15	-0.91	
47.54	-1.46	-1.14	
71.44	-1.50	-1.16	Slack or Pressed Up

Note: Table values for wing tanks are for both tanks filled to the level indicated.

APPROXIMATE GAIN IN GM BY BALLASTING OR DEBALLASTING

MEAN DRAFT (FT.)	F.P. 3095	W.T.#1 P&S 9008	U.W.T.#2 P&S 2565	L.W.T.#2 P&S 7712	U.W.T.#3 P&S 2923	L.W.T.#3 P&S 7062	U.W.T.#4 P&S 1056	L.W.T.#4 P&S [illegible]	U.W.T.#5 P&S 2418	L.W.T.#5 P&S 7062	U.W.T.#6 P&S 2923	L.W.T.#6 P&S 6780	W.T.#7 P&S 5338	D.B. 902	AFT D.T. 6343	A.P. 2150	S.T.#1 4017	S.T.#2 2727
	GAIN IN GM BY BALLASTING (IN FEET) — S.W. BALLAST TANK, CAPACITY (IN LONG TONS)																	
30	-0.7	-1.1	-2.1	0.1	-2.2	0.4	-0.8	0.1	-2.0	0.4	-2.2	0.3	-3.4	0.1	-1.2	-0.6	-2.2	-1.6
32	-0.3	0.6	-1.6	0.6	-1.7	0.8	-0.6	0.4	-1.5	0.8	-1.7	0.7	-1.7	0.3	-0.6	-0.3	-1.8	-1.2
34	-0.2	-0.2	-1.5	0.7	-1.6	1.0	-0.6	0.4	-1.4	1.0	-1.6	0.8	-1.5	0.2	-0.4	-0.3	-1.6	-1.2
36	-0.3	-0.1	-1.4	0.8	-1.5	1.0	-0.6	0.4	-1.3	1.0	-1.5	0.9	-1.4	0.2	-0.4	-0.3	-1.5	-1.0
38	-0.2	0.1	-1.2	0.9	-1.2	1.2	-0.4	0.5	-1.1	1.2	-1.2	1.1	-1.1	0.3	-0.2	-0.2	-1.3	-0.8
40	-0.1	0.2	-1.1	1.0	-1.2	1.2	-0.4	0.5	-1.0	1.2	-1.2	1.1	-1.1	0.2	-0.2	-0.1	-1.2	-0.8
	GAIN IN GM BY DEBALLASTING (IN FEET)																	
30	0.5	1.2	1.8	-0.4	1.9	-0.9	0.6	-0.5	1.7	-0.9	1.9	-0.7	2.4	-0.3	0.9	0.5	2.3	1.4
32	0.5	0.6	1.7	-0.7	1.8	-1.1	0.8	-0.4	1.6	-1.1	1.8	-0.9	2.0	-0.1	0.6	0.4	2.0	1.3
34	0.5	0.5	1.6	-0.8	1.7	-1.2	0.8	-0.4	1.6	-1.2	1.7	-1.0	1.3	-0.1	0.5	0.4	1.9	1.2
36	0.0	-0.2	1.2	-1.2	1.3	-1.5	0.5	-0.7	1.1	-1.5	1.3	-1.3	1.3	-0.2	0.1	0.2	1.3	0.8
38	0.2	-0.2	1.2	-1.2	1.2	-1.4	0.5	-0.6	1.1	-1.4	1.2	-1.2	1.1	-0.2	0.0	0.2	1.3	0.8
40	0.1	-0.3	1.1	-1.3	1.2	-1.5	0.4	-0.6	1.0	-1.5	1.2	-1.4	1.0	-0.2	-0.1	0.2	1.2	0.7

NOTES: 1. THE UPPER TABLE GIVES THE APPROXIMATE GAIN IN GM OBTAINED BY COMPLETELY FILLING ANY BALLAST TANK WHICH IS INITIALLY EMPTY. THE LOWER TABLE GIVES THE APPROXIMATE GAIN IN GM OBTAINED BY COMPLETELY EMPTYING ANY BALLAST TANK WHICH IS INITIALLY FULL. A NEGATIVE NUMBER INDICATES A DECREASE IN GM.

2. ENTER THE APPROPRIATE TABLE AT THE SHIP'S INITIAL DRAFT AND READ THE INCREASE IN GM FOR THE TANK OR TANK PAIR INVOLVED. LINEAR INTERPOLATION BETWEEN THE TABULATED DRAFTS IS PERMISSIBLE.

4. THE VESSEL HAS BEEN REVIEWED FOR DAMAGE STABILITY ASSUMING THE FOLLOWING EXTENT OF DAMAGE OCCURRING ANYWHERE ALONG THE VESSEL'S LENGTH:

LONGITUDINAL EXTENT	46'-8"
TRANSVERSE PENETRATION	27'-0"
VERTICAL EXTENT	FROM BASELINE UPWARDS WITHOUT LIMIT

B) BOTTOM DAMAGE:

LONGITUDINAL EXTENT	46'-8"
TRANSVERSE EXTENT	22'-6"
VERTICAL PENETRATION	6"-7"

WITH THESE ASSUMPTIONS, THE VESSEL HAS BEEN FOUND TO REMAIN AFLOAT IN A SATISFACTORY CONDITION OF EQUILIBRIUM.

DAMAGED STABILITY

1. Extent of Damage

a) Side Penetration

(1) Longitudinal Extent – 46.50 ft.
(2) Transverse Extent – 28.70 ft.
(3) Vertical Extent – Baseline upward without limit.

b) Bottom Penetration – Forward 0.3 Length

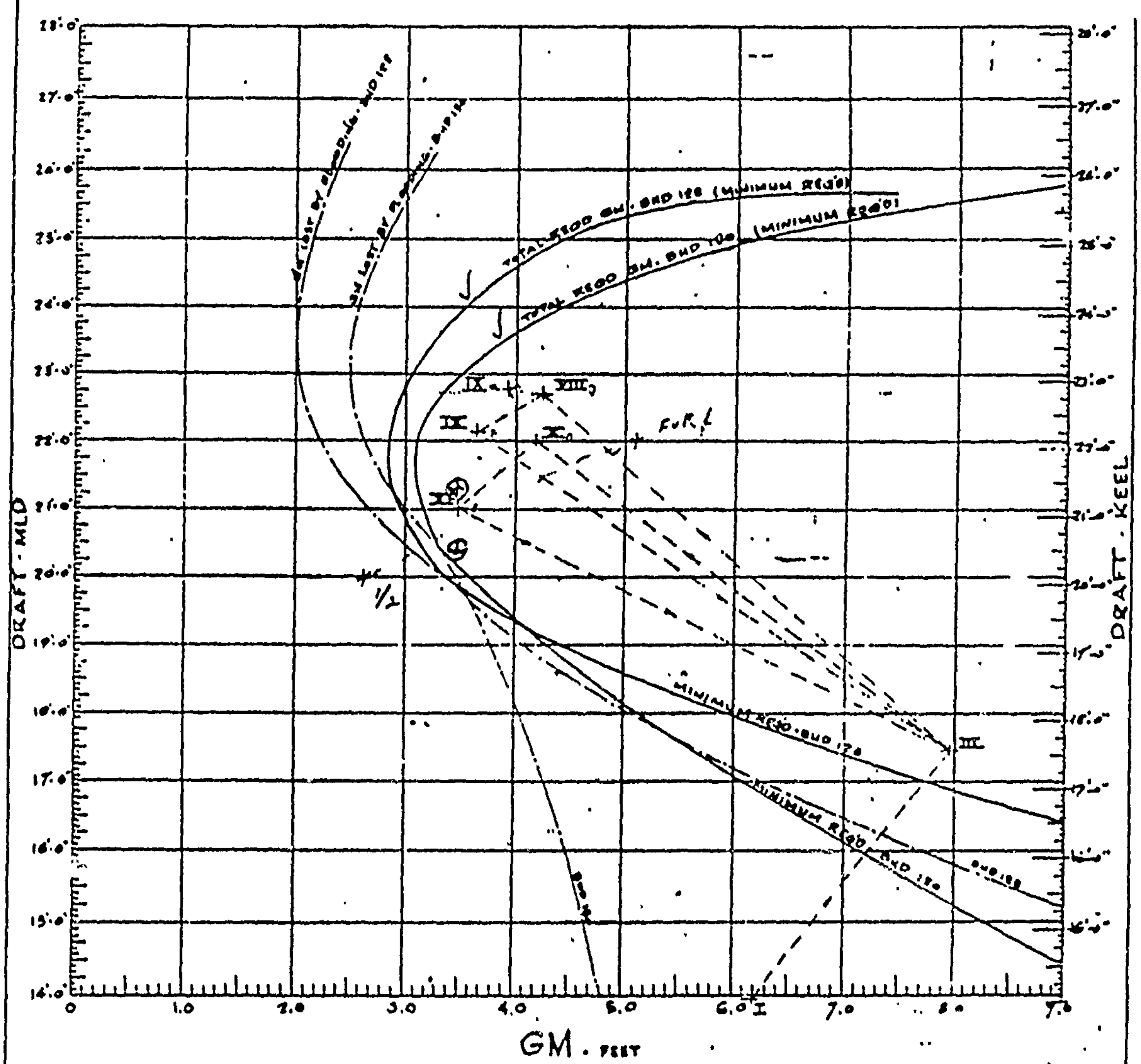
(1) Longitudinal Extent – 46.50 ft.
(2) Transverse Extent – 23.92 ft.
(3) Vertical Extent – 6.56 ft.

c) Bottom Penetration – Aft 0.7 Length

(1) Longitudinal Extent – 16.41 ft.
(2) Transverse Extent – 16.41 ft.
(3) Vertical Extent – 6.56 ft.

d) Local Damage – 29.9 inches in depth, normal to the hull.

Side penetration is assumed to occur anywhere along the length of the hull. Bottom penetration is assumed to occur anywhere within the limits specified. Local damage can occur anywhere on the hull.



THE ROMAN NUMERALS CORRESPOND TO THE LOADING CONDITIONS GIVEN IN DETAIL ON THE PRECEDING PAGES.

THE LIMIT FOR IMMERSION IS THE MODIFIED MARGIN LINE, I.E., 3" BELOW THE MAIN DECK AT SIDE FROM STEM TO BHD 128. ALL MAIN DECK OPENINGS FROM BHD 128 TO STERN ARE ASSUMED WATERTIGHT, HENCE STERN SUBMERGENCE TO MARGIN LINE AT BHD 128 IS ALLOWED (PER MARAD LETTER [redacted]

HEELING AFTER DAMAGE IS LIMITED TO 15° OR IMMERSION OF THE MARGIN LINE WHICHEVER OCCURS FIRST.

THE CONTINUOUS CURVES GIVE THE MINIMUM REQUIRED INTACT GM, EITHER TO LIMIT HEEL DUE TO UNSYMMETRICAL BUOYANCY OR TO MAINTAIN POSITIVE GM AFTER DAMAGE. THE DIFFERENCE BETWEEN THE TOTAL REQUIRED GM AND THE GM LOST DUE TO FLOODING IS THE RESIDUAL GM REQUIRED TO LIMIT HEEL.

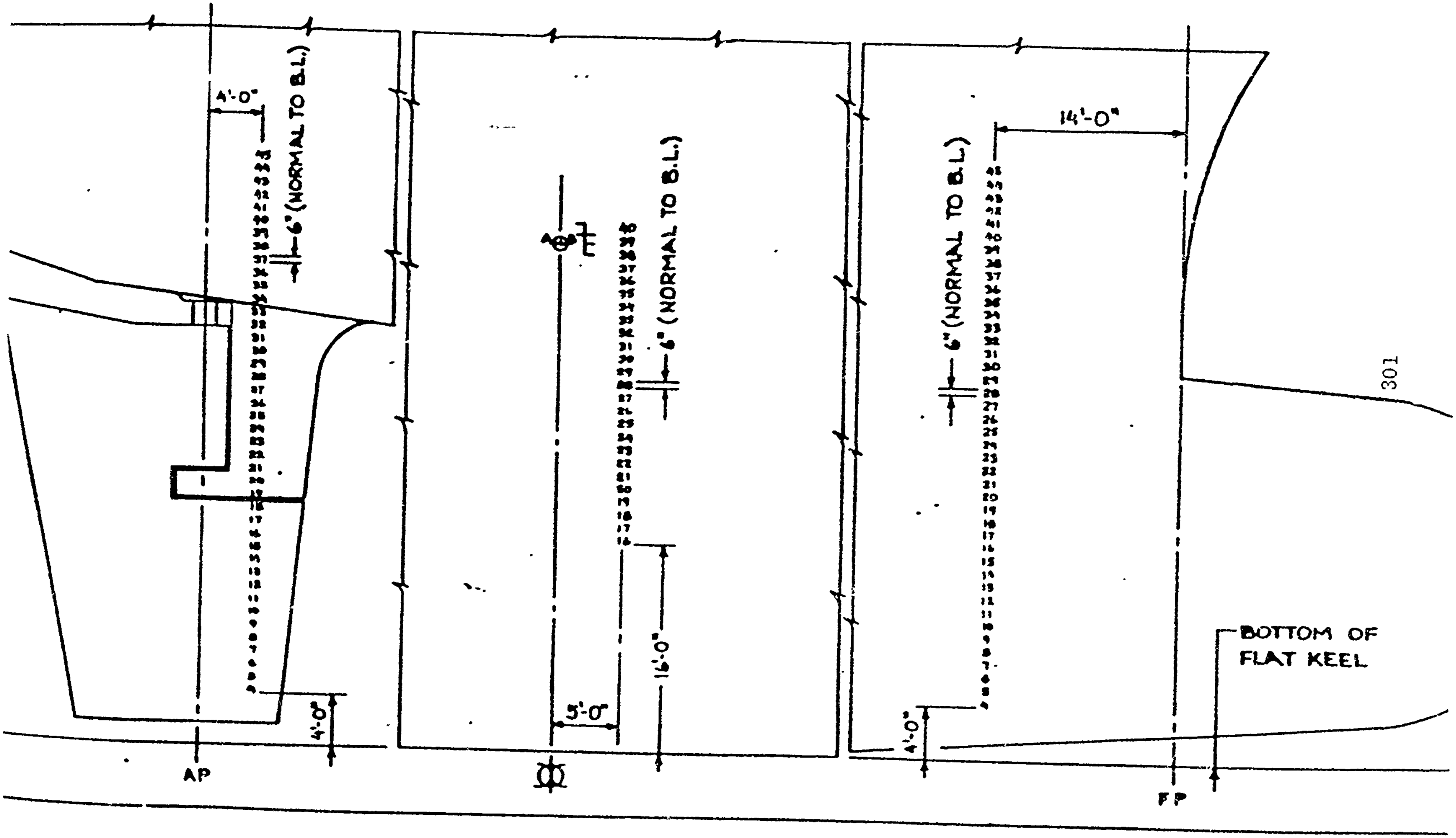
ALL CALCULATIONS ARE BASED ON DISPLACEMENTS AT EVEN KEEL BEFORE DAMAGE. ACTUAL TRIM LINES AND SHIP'S CHARACTERISTICS ARE USED FOR DAMAGED & HEELED CONDITIONS; NO EMPIRICAL FORMULATIONS OR CONSTANTS ARE EMPLOYED. EXTENT OF DAMAGE IS GENERALLY THAT WHICH IS REASONABLE OR GOVERNED BY CONVENTION. 75% PERMEABILITY IS ASSUMED IN ALL VEHICLE SPACES.

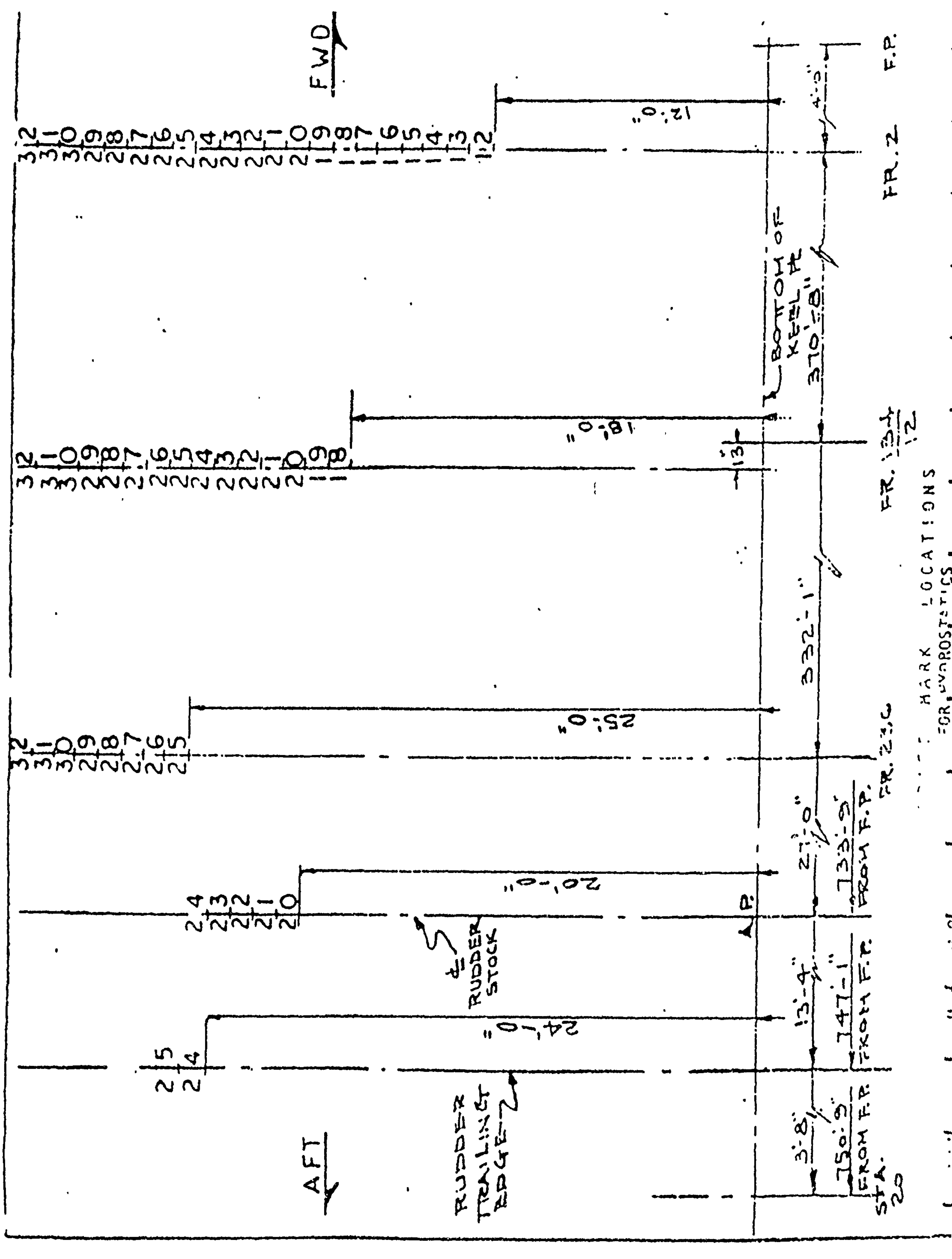
DAMAGE AT EITHER BHD 88 OR BHD 107 IS LESS SEVERE THAN THE GIVEN BHD 128 AND BHD 170 CURVES.

DAMAGED STABILITY

VEHICLE LOAD - TWO COMPARTMENT SUBDIVISION

DRAFT MARK LOCATIONS




FWD
AFT
F.P.
FR. 2
12'-0"
4'-0"
BOTTOM OF KEEL PL
370'-8"
18'-0"
FR. 13 1/2
332'-1"
25'-0"
20'-0"
27'-0"
733'-9" FROM F.P.
A.P.
℄ RUDDER STOCK
24'-0"
13'-4"
747'-1" FROM F.P.
RUDDER TRAILING EDGE
3'-8"
750'-9" FROM F.P.
STA. 20

LONGITUDINAL STRENGTH

LOAD ITEM	FACTOR	WT. (LT/100)	NUMERAL HOG +	NUMERAL − SAG
CARGO TANK NO. 1	0.396			—
NO. 2	-0.195		—	
NO. 3	-0.643		—	
NO. 4	-0.291		—	
NO. 5	0.278			—
F. O. NO. 1 & NO. 2	0.830			—
F. O. NO. 3 & NO. 4	0.574			—
F. O. NO. 5 {OILY WATER, FO SLUDGE, SEWAGE}	0.684			—
F. O. NO. 6	0.714			—
AFT PEAK, F. O. NO. 7	1.098			—
D. O. NO. 1 & NO. 2	0.864			—
L. O. - STR. & SETT.	0.791			—
POT. W. NO. 1 & NO. 2	0.859			—
R. F. W. NO. 1 & NO. 2	1.035			—
S. W. NO. 1	0.714			—
S. W. NO. 2 P & S	0.540			—
S. W. NO. 3 P & S	0.209			—
S. W. NO. 4 P & S	-0.046		—	
S. W. NO. 5 (STAB.)	-0.374		—	
S. W. NO. 6 P & S	-0.635		—	
S. W. NO. 7 (STAB.)	-0.687		—	
S. W. NO. 8 P & S	-0.425		—	
S. W. NO. 9 (STAB.)	-0.119		—	
S. W. NO. 10 P & S	0.127			—
S. W. NO. 11 P & S	0.441			—
FULL LOAD STAB. 8 ℄	-0.532		—	
NITROGEN STORAGE	-0.478		—	
SWIMMING POOL	0.880			—
TOTAL DWT ITEMS				
LIGHTSHIP, INCL CREW, EFFECTS & STORES		+	+ 94.44	—
SHIP (=DWT ITEMS + LIGHTSHIP)		______	______	______
		TOTAL WT/100	NET NUMERAL	

NET NUMERAL MUST BE BETWEEN -100 AND +100.

3.5 The distance between the vessel's LCG and LCF is the trim lever. The product of displacement and trim lever is the moment causing the vessel to trim.

When such moment is divided by the "Moment to trim one inch", page 10, multiplied by 12, the vessel's total trim in feet, as measured on the perpendiculars is determined. (When LCG is aft of LCB, the vessel trims aft, and vice versa.) The portion of this trim to be applied to the aft perpendicular is obtained by dividing the distance from the aft perpendicular to the LCF by the length between perpendiculars times total trim.

The remainder of the trim is applied at the forward perpendicular. Drafts on perpendiculars are found by adding or subtracting the portions of the trim to the mean draft corresponding to the total displacement.

4. CALCULATION OF RIGHTING ARMS

4.1 From the Cross Curves of Stability, page 11, using the appropriate displacement, read off and enter on the form, the uncorrected righting arms, for 10°, 20°, 30°, 45°, 60°, and 75°.

4.2 On the next line of the form, enter under each column the KG value for the upright ship, obtained from the last line of the "Summary" block of the form.

4.3 Copy from the "Stability" block of the form the allowance for free surface, entering this under each column.

4.4 Add the two items above (the KG and the free surface addition) to give the virtual KG.

4.5 Multiply the virtual KG by the sine of each of the listed angles of inclination. The sine values are already printed on the form.

4.6 Subtract the values of KG sine from the uncorrected righting arm, to give the corrected righting arm.

4.7 The corrected righting arms may now be plotted [illegible] on the grid form. By plotting the corrected GM at 57.3° point and drawing a straight line from this point back to zero, the tangent to the righting arm curve will be obtained. The plotted curve should follow this straight line from about zero to 5 degrees. Note that [illegible] example calculations, the scale for the righting arm values [illegible] take into account the fact that some conditions have a much higher righting arm than others; adjustment of the vertical scale permits the curves to fit on the available grid on the form.

5. DETERMINATION OF STRESS NUMERAL

5.1 The stress numeral is the percentage of the maximum designed stress that will occur for the loading condition under consideration. To determine this the still water bending moment must be obtained, and it is estimated by use of the "Stress Numeral" block of the Trim and Stability Form.

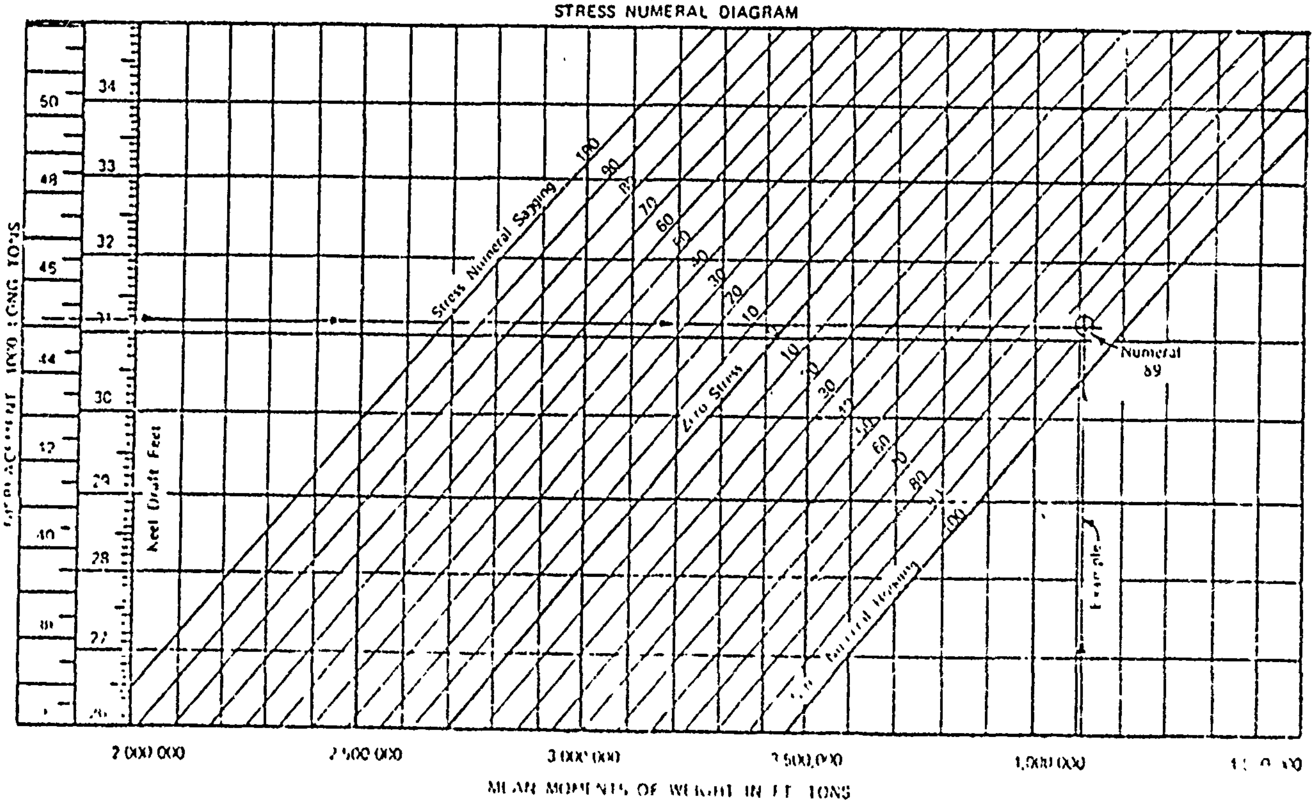
5.2 It will be noted in the "Summary" block of the form that the deadweight moments about midships are totalled separately aft and forward. These aft and forward moments are to be entered in Lines (1) and (2) of the "Stress Numeral" block, and then added numerically and the sum divided by 2.0 to obtain the mean deadweight moment (Line 3).

5.3 The mean deadweight moment (3), when added to the constant predetermined value of the light ship moment (4), the total (5) is the mean longitudinal moment of displacement (5).

5.4 Using Pacific Eastbound Departure as an example, and entering the chart on Fig. 1 with the displacement of 45,112 tons and the mean moment of displacement of 4,106,577 the intersection of these two values is the stress numeral. A typical example is shown on this chart, which shows that the bending moment is hogging and that the stress numeral is 89 which means that the stress for the sample loading is 89 percent of the designed moment of the ship.

5.5 Since the method is an approximation stress numerals should be maintained below 95 to provide a degree of margin to insure that the actual stress is in fact less than the designed stress.

Figure 1
STRESS NUMERAL DIAGRAM



ALLOWABLE SHEARING FORCE AND BENDING MOMENT (STILL WATER) VALUES

FR NO.	LCG.	SHEAR FORCE TONS	BENDING MOMENT 20' - 40' ft.tns.	BENDING MOMENT 40' - 57.25' ft.tns.	HARBOR CONDITION	
					SHEAR FORCE Tons	BENDING MOMENT Ft-Tons
70	735.0	8,750	755,600	179,200	12,820	1,307,196
68	707.667	10,772	1,069,700	289,800	15,838	2,065,000
66	674.0	10,876	1,490,000	464,700	16,480	2,410,000
58	539.33	15,560	1,798,400	606,400	20,644	2,707,195
52	438.33	13,538	1,625,600	548,000	17,125	2,707,195
42	270.0	14,464	753,600	296,000	20,013	2,707,195
36	169.0	11,296	329,600	199,200	17,125	2,315,000
29	58.0	6,115	175,000	175,000	9,214	751,228

70 FRAME

BUOYANCY AND BUOYANCY MOMENT CALCULATION TABLE

[illegible]CEMENT [illegible]TONS	BUOYANCY LONG.TONS	CHANGE BUOY./TON FT. TONS	CHANGE BUOY./FT. TRIM LONG.TONS DML 860	DML 822	BUOY.MOMT LONG-TONS.	CHANGE BUOY.MOMT./TON. LONG.TONS	CHANGE BUOY.MOMT./FT.TRIM FT. TONS DML 860	DML 822
[illegible].000	0.671	0.035		0.052	516.867	27.072		40.371
[illegible].000	0.881	0.037		0.055	679.302	28.217		42.270
[illegible].000	1.248	0.038		0.058	961.474	29.593		44.010
[illegible].000	1.632	0.039		0.060	1257.401	30.361		46.440
[illegible].000	2.026	0.041		0.063	1561.009	31.444		48.503
[illegible].000	2.435	0.043	0.063	0.066	1875.447	32.939	48.678	51.019
[illegible].000	2.864	0.045	0.068	0.071	2204.835	34.802	52.013	54.543
[illegible].000	3.317	0.049	0.073	0.077	2552.856	37.628	56.575	59.308
[illegible].000	3.807	0.053	0.081	0.086	2929.140	41.147	62.924	66.082
[illegible].000	4.341	[illegible]	0.092	0.096	3340.609	46.118	71.025	74.649
[illegible].000	4.939	0.067	0.104	0.109	3801.793	51.649	80.741	85.233
[illegible].000	5.605	0.075	0.118	0.124	4318.285	58.222	92.105	96.862
[illegible].000	6.353	0.083	0.132	0.138	4900.504	65.232	103.622	108.659
[illegible].000	7.187	0.091	0.145	0.152	5552.820	71.577	115.004	120.699
[illegible]0.000	8.097	0.099	0.158	0.165	6268.594	78.244	125.205	131.322
[illegible]0.000	9.088	0.105	0.167	0.176	7051.039	83.142	133.467	139.936
[illegible]0.000	10.138	0.110	0.176	0.185	7882.453	87.634	140.852	147.644
[illegible]0.000	11.242	0.115	0.184	0.193	8758.801	91.680	147.301	154.295
[illegible]0.000	12.394	0.119	0.190	0.199	9675.602	94.453	152.[illegible]	159.[illegible]

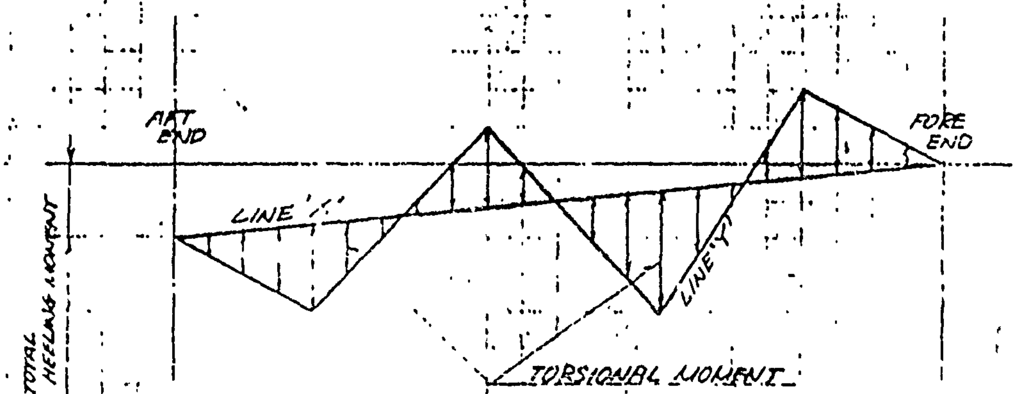
3.4 Torsional moment calculation

Torsional moment is caused by the unbalanced loading of containers, fuel oil, fresh water, ballast water and so on. The value of torsional moment corresponds to the difference between line 'X' and line 'Y' in the following figure.

where

line 'X' straight line from Fore End to the total heeling moment

line 'Y' moment integrated line from Fore End



Torsional moment at each section is given as follows,

		(Allowable torsional moment)
Fr. 145	|0.237 F - A|	2,500 MT-M
Fr. 13[illegible]	|0.365 F - B|	"
Fr. 12[illegible]	|0.493 F - C|	"
Fr. 11[illegible]	|0.609 F - D|	"
Fr. [illegible]	|0.878 F - E|	"

(EXAMPLE)

Calculation example is shown on page 93 ~ 96.
containers (only BAY 11,32,39), fuel oil, fresh water and ballast water are unbalanced load in this example.

********* ********* ********* *********

Sample of calculation forms are on page 97 ~ 135.

(1/38)

CALCULATION SHEET FOR TORSIONAL MOMENT

(+) sign shows "Port side" moment
(−) sign shows "Starboard side" moment

Fr. No.	20' CONTAINER BAY NO.	MOMENT	SUM. ①	40' CONTAINER BAY NO.	MOMENT	SUM. ②	TANKS TANK. NAME	W.T. (MT)	T.CG (M)	MOMENT	SUM. ③	GRAND TOTAL ①+②-③
	01		ST(a)									TORSIONAL MOMENT
	03											(0.237F-A)
	05											
	07			04		ST(a)						M-M
	09			08								
145			(a)			(a)						(A)
	11		ST(b)				NO.3 L.W.T.(P)		+9.61		ST(b)	TORSIONAL MOMENT
	13						〃 (S)		-9.61			(0.365F-B)
	15			12		ST(b)	NO.3 U.W.T.(P)		+14.12			M-M
	17			16			〃 (S)		-14.12			
135			(a)+(b)			(a)+(b)					(b)	(B)
	19		ST(c)				NO.4 L.W.T.(P)		+11.00		ST(c)	TORSIONAL MOMENT
	21						〃 (S)		-11.00			(0.493F-C)
	23			20		ST(c)	NO.4 U.W.T.(P)		+14.43			M-M
	25			24			〃 (S)		-14.43			
125			(a)+(b)+(c)			(a)+(b)+(c)					(b)+(c)	(C)
							NO.5 L.W.T.(P)		+12.95		ST(d)	TORSIONAL MOMENT
							〃 (S)		-12.95			(0.609F-D)
	27		ST(d)				NO.5 W.B.T.(P)		+3.63			
	29						〃 (S)		-3.63			M-M
	31			28		ST(d)	NO.5 U.W.T.(P)		+14.46			
	33			32			〃 (S)		-14.46			
116			(a)+⋯+(d)			(a)+⋯+(d)					(b)+(c)+(d)	(D)
							C-OIL SETT.T. (P)		+14.04		ST(e)	TORSIONAL MOMENT
							(S)		-14.04			(0.878F-E)
							C-OIL SERV.T. (P)		+11.16			
							(S)		-11.16			
							~~NO.~~6 F.O.T.(P)		+10.40			
							〃 (S)		-10.04			
							A-OIL SETT.T.(S)		-11.16			M-M
							A-OIL SERV.T.(S)		-11.16			
	35		ST(e)				FRESH W.T. (P)		+14.46			
	37						〃 (S)		-14.46			
	39			36		ST(e)	NO.6 L.W.T.(P)		+13.75			
	41			40			〃 (S)		-13.75			
45			(a)+⋯+(e)			(a)+⋯+(e)					(b)+⋯+(e)	(E)
	43		ST(f)									
	45											
	47			44		ST(f)						
	49			48								
8			(a)+⋯+(f)			(a)+⋯+(f)					(b)+⋯+(f)	(F)

ALLOWABLE TORSIONAL MOMENT
= 9,500 M.T.-M

c.f. (F); Total heeling moment
ST; Sub. total

GENERAL NOTES

REMARKS

OPERATING RESTRICTIONS

1. In the 20' to 40' draft range, the forepeak ballast tank is restricted to a maximum of 2000 long tons, to limit the (hogging) bending moment. In the gale ballast conditions, a minimum of 4000 long tons must be carried in the forepeak to limit the shear force at Frame 58.

2. In the 20'-40' draft range, if the total fuel oil on board exceeds 1920 long tons, the afterpeak tank must be empty to limit the shear force at Frame 70.

3. In the partial load (wings only) condition, a minimum of 4000 long tons ballast must be carried in the No. 2 Port and Stbd Ballast Tanks to limit trim.

4. All sluice valves connecting adjacent cargo tanks are to be kept closed at all times, except during loading or unloading the cargo. In the event of damage to the vessel during loading or unloading, all the sluice valves must be closed immediately.

5. All loading conditions must be verified (with the help of the loading manual) before proceeding to sea; to ensure adequate longidutinal strength.

6. If the vessel is to be loaded in any other manner than a normal full load or normal ballast condition, the following conditions are necessary to satisfy damaged stability requirements: either the cargo wings must be at least 75% full, or the ballast wings must be 100% full. If the vessel's draft is to exceed 40 feet, the cargo wings must be at least 75% full. Should the vessel's draft exceed 50 feet, the No. 3 wings must be at least 27% full in conjunction with the 75% full requirement of the 1 and 5 wings. (See Page 6 of ASI Dwg. 29-01-07) Rev. [illegible].

GAIN IN GM (FT) BY BALLASTING TANKS

	S.W. BALLASTING TANKS		TOTAL DISPLACEMENT (L. TONS)							
No.	Tank	100% L.Tons	28,000	26,000	24,000					
1.	Double Bottom P.&S.									
2.	Double Bottom									
2.	Double Bottom P.&S.									
3.	Double Bottom									
3.	Double Bottom P.&S.									
4.	Double Bottom									
4.	Double Bottom P.&S.									
5.	Double Bottom P.&S.									
M1	Double Bottom P.&S.									
	Fore Peak Tank									
	Aft Peak Tank									

Note: The values given above do not include any allowance for loss in GM due to the free surface of the ballasting liquid.

GAIN IN GM (FT) BY BALLASTING TANKS

S.W. BALLASTING TANKS			TOTAL DISPLACEMENT (L. TONS)							
No.	Tank	100% L.Tons	28,000	26,000	24,000					
1.	Double Bottom P.&S.									
2.	Double Bottom									
2.	Double Bottom P.&S.									
3.	Double Bottom									
3.	Double Bottom P.&S.									
4.	Double Bottom									
4.	Double Bottom P.&S.									
5.	Double Bottom P.&S.									
M1	Double Bottom P.&S.									
	Fore Peak Tank									
	Aft Peak Tank									

Note: The values given above do not include any allowance for loss in GM due to the free surface of the ballasting liquid.

INSTRUCTIONS FOR COMPUTATION OF VESSEL'S STABILITY AND TRIM (LONG FORM)

1. IN CALCULATING THE VESSEL'S TRIM AND STABILITY FOR ANY CONDITION OF LOADING, THE DETAIL WEIGHTS IN EACH CATEGORY SUCH AS CARGO, FUEL OIL, BALLAST, AND FRESH WATER ARE ENTERED IN SEPARATE DETAILED LOADING TABLES ON PAGES 38-48, TOGETHER WITH THE VERTICAL AND LONGITUDINAL CENTERS FOR EACH ITEM. APPROPRIATE FREE SURFACES FOR THE SETTLERS AND FOR EACH STORAGE TANK CONTAINING CONSUMABLE LIQUIDS WHICH IS NOT PRESSED UP SHALL BE ENTERED FROM THE TABLE ON PAGE NO. L2. "SLACK" FREE SURFACE SHALL BE ENTERED FOR THE SETTLERS. THE "SLACK" FREE SURFACE ENTERED FOR THE CONSUMABLE LIQUID STORAGE TANKS SHALL RESULT IN A SUM NOT LESS THAN THE TANK PAIR VALUES WHICH ARE THE LARGEST, FOR EACH TYPE OF CONSUMABLE LIQUID ON BOARD. THIS REQUIREMENT WILL ALLOW USE OF THE VESSEL'S TANKAGE IN ANY ORDER DESIRED WITHOUT UNDETECTED LOW STABILITY DUE TO FREE SURFACE OCCURRING AT ANY TIME DURING THE VOYAGE. (SEE ROUTINE OPERATING INSTRUCTION NO. 2.) ALL OTHER 98% FULL FUEL OIL TANKS SHALL HAVE 98% - 5 DEGREE HEEL FREE SURFACE ENTERED FOR THEM. IN THE SEPARATE DETAIL LOADING TABLES, EACH CATEGORY IS SUMMED WITH RESPECT TO TONNAGE, VERTICAL MOMENT, LONGITUDINAL MOMENT AND FREE SURFACE. (MOMENT IS THE PRODUCT OF TONNAGE BY CENTER OF GRAVITY DISTANCE FOR EACH ITEM.)

(ORATOR)

Instructions for Computation of Vessel's Stability and Trim (Long Form)

1. In calculating the vessel's trim and stability for any condition of loading, the detail weights in each category such as cargo, fuel oil, ballast, and fresh water are entered in separate detailed loading tables on Pages 38-48, together with the vertical and longitudinal centers for each item. Appropriate free surfaces for the settlers and for each storage tank containing consumable liquids which is not pressed up shall be entered from the table on Page No. 12. "Slack" free surface shall be entered for the settlers. The "Slack" free surface entered for the consumable liquid storage tanks shall result in a sum not less than the tank pair values which are the largest, for each type of consumable liquid on board. This requirement will allow use of the vessel's tankage in any order desired without undetected low stability due to free surface occurring at any time during the voyage. (See Routine Operating Instruction No. 2.) All other 98% full fuel oil tanks shall have 98% - 5 degree heel free surface entered for them. In the separate detail loading tables, each category is summed with respect to tonnage, vertical moment, longitudinal moment and free surface. (Moment is the product of tonnage by center of gravity distance for each item.)

(COURIER)

Instructions for Computation of Vessel's Stability and Trim (Long Form)

1. In calculating the vessel's trim and stability for any condition of loading, the detail weights in each category such as cargo, fuel oil, ballast, and fresh water are entered in separate detailed loading tables on Pages 38-48, together with the vertical and longitudinal centers for each item. Appropriate free surfaces for the settlers and for each storage tank containing consumable liquids which is not pressed up shall be entered from the table on Page No. 12. "Slack" free surface shall be entered for the settlers. The "Slack" free surface entered for the consumable liquid storage tanks shall result in a sum not less than the tank pair values which are the largest, for each type of consumable liquid on board. This requirement will allow use of the vessel's tankage in any order desired without undetected low stability due to free surface occurring at any time during the voyage. (See Routine Operating Instruction No. 2.) All other 98% full fuel oil tanks shall have 98% - 5 degree heel free surface entered for them. In the separate detail loading tables, each category is summed with respect to tonnage, vertical moment, longitudinal moment and free surface. (Moment is the product of tonnage by center of gravity distance for each item.)

(BOOKFACE)

Instructions for Computation of Vessel's Stability and Trim (Long Form)

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(GOTHIC)

GAIN IN GM (FT) BY BALLASTING TANKS

S.W. BALLASTING TANKS			TOTAL DISPLACEMENT (L. TONS)		
No.	Tank	100% L.Tons	28,000	26,000	24,000
1.	Double Bottom P.&S.	336	.33	.33	.35
2.	Double Bottom	459	.47	.46	.48
2.	Double Bottom P.&S.	296	.29	.29	.30
3.	Double Bottom	473	.48	.48	.50
3.	Double Bottom P.&S.	480	.49	.47	.50
4.	Double Bottom	483	.49	.48	.51
4.	Double Bottom P.&S.	446	.45	.45	.46
5.	Double Bottom P.&S.	200	.20	.19	.21
M1	Double Bottom P.&S.	216	.22	.21	.23
	Fore Peak Tank	259	.06	.06	.04
	Aft Peak Tank	252	0	-.02	-.03

Note: The values given above do not include any allowance for loss in GM due to the free surface of the ballasting liquid.

GAIN IN GM (FT) BY BALLASTING TANKS

S.W. BALLASTING TANKS			TOTAL DISPLACEMENT (L. TONS)		
No.	Tank	100% L.Tons	28,000	26,000	24,000
1.	Double Bottom P.&S.	336	.33	.33	.35
2.	Double Bottom	459	.47	.46	.48
2.	Double Bottom P.&S.	296	.29	.29	.30
3.	Double Bottom	473	.48	.48	.50
3.	Double Bottom P.&S.	480	.49	.47	.50
4.	Double Bottom	483	.49	.48	.51
4.	Double Bottom P.&S.	446	.45	.45	.45
5.	Double Bottom P.&S.	200	.20	.19	.21
M1	Double Bottom, P.&S.	216	.22	.21	.23
	Fore Peak Tank	259	.06	.06	.04
	Aft Peak Tank	252	0	-.02	-.03

Note: The values given above do not include any allowance for loss in GM due to the free surface of the ballasting liquid.

PAGES ______
ARE
MISSING
IN
ORIGINAL
DOCUMENT

GAIN IN GM (FT) BY BALLASTING TANKS

S.W. BALLASTING TANKS			TOTAL DISPLACEMENT (L. TONS)							
No.	Tank	100% L.Tons	28,000	26,000	24,000					
1.	Double Bottom P.&S.	336	.33	.33	.35					
2.	Double Bottom	459	.47	.46	.48					
2.	Double Bottom P.&S.	296	.29	.29	.30					
3.	Double Bottom	473	.48	.48	.50					
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M1	Double Bottom P.&S.	216	.22	.21	.23					
	Fore Peak Tank	259	.06	.06	.04					
	Aft Peak Tank	252	0.0	-.02	-.03					

Note: The values given above do not include any allowance for loss in GM due to the free surface of the ballasting liquid.

GAIN IN (FT) BY BALLASTING TANKS

S.W. BALLASTING TANKS				TOTAL DISPLACEMENT (L. TONS)		
NO.	TANK		100% L.TONS	28,000	26,000	24,000
1. 2.	Double Bottom Double Bottom	P.&S.				
2. 3.	Double Bottom Double Bottom	P.&S.				
3. 4.	Double Bottom Double Bottom	P.&S.				
4. 5.	Double Bottom Double Bottom	P.&S. P.&S.				
M1	Double Bottom Fore Peak Tank	P.&S.				
	Aft Peak Tank					

NOTE: The values given above to not include any allowance for loss in GM due to the free surface of the ballasting liquid.

SECOND WORKSHOP MATERIAL

Please tell me how you feel about these statements concerning stability and longitudinal strength. Answer every question.

	STRONGLY AGREE	AGREE	UNCERTAIN	DISAGREE	STRONGLY DISAGREE	COMMENTS
1. A vessel's speed is significant in determining the way the ship rolls.						
2. Significant benefits result from sailing with an additional margin on GM.						
3. Windheel and damage stability curves are the technical determinants of the required GM curve.						
4. T&S booklets do not adequately consider inaccuracies in cargo weights and centers of gravity.						
5. Displacement directly affects the rolling period of the vessel.						
6. Calculated draft, trim, and stability can agree with the vessel's marks but the actual GM can differ from the calculated GM.						

We would like your opinions on the following statements about the trim and stability or trim and stength booklet. Please answer every question. Your comments would help us to develop sound recommendations for the T&S booklet - please make comments freely.

7. The T&S booklet should concentrate on safety functions and include only material needed to judge transverse stability, trim, and longitudinal strength.						

	STRONGLY AGREE	AGREE	UNCERTAIN	DISAGREE	STRONGLY DISAGREE	COMMENTS
8. The form and layout of the T&S calculation is very important to accurate, fast results.						
9. T&S booklets should be standardized for each type of vessel, e.g. tankship, containership.						
10. Standards of design and reproduction of T&S booklets should be improved.						
11. The Z nomograph short form should be discarded.						
12. Other short forms should be discarded.						
13. The number of loading examples should be minimal.						
14. Loading examples should be realistic rather than related to MarAd or other regulatory body requirements.						
15. The loading examples should be replaced by full instructions on each table or worksheet.						
16. All safety standards for the vessel should be treated in the T&S booklet, even where this means combining the Coast Guard and classification society booklets.						

These statements refer to particular parts and tables in the T&S booklet. We added columns headed "Use frequently" and "Use seldom/never". Please show us whether you do in fact use the item before going on to evaluate it and add ur comments.

	STRONGLY AGREE	AGREE	UNCERTAIN	DISAGREE	STRONGLY DISAGREE	COMMENTS
17. The trim table consistently gives accurate results - it agrees with the actual drafts within 3" and always indicates currectly whether my vessel is trimmed by the head or stern.						
The instructions for using the T&S booklet, in their present form, are 18. necessary						
19. helpful						
The operating instructions, if any, 20. agree with the loading manual and other documents.						
21. are fully explained in the T&S booklet.						
The hydrostatic particulars 22. should be given in a tabular form.						
23. at 3" draft intervals.						

	STRONGLY AGREE	AGREE	UNCERTAIN	DISAGREE	STRONGLY DISAGREE	COMMENTS
24. The table or graph of required GM tells precisely what GM is needed at any given draft.						
25. Cargo space and capacity data in the booklet correspond with terminal documents and figures.						
26. The table of change in GM due to ballasting is accurate.						
27. Which format is preferred overall - new or original?						
28. Which do you prefer - text instructions or step-by-step, like the original instructions?						
29. Does a grid composed of solid and dotted lines seem easier for you to follow?						
30. Do you like the idea of a commercially printed set of forms for working stability/strength, rather than the T&S booklet forms?						

LOADING SUMMARY SHEET

ITEM	WEIGHT L-TONS	LCG FROM F.P. FT	LONGIT MOMENT FT-TONS	VCG ABOVE B.L. FT	VERTICAL MOMENT FT-TONS	TCG FROM C.L. FT	TRANSVERSE MOMENT FT-L.TONS	FREE SURFACE FT-L.TONS
Lightship	24707.5	474.10		44.40		0.09		
Crew/Stores								
Cargo Oil								
Ballast								
Fuel/Diesel								
Lube Oil								
Fresh/Potable Water								
Miscellaneous								
TOTAL								

TRIM AND STABILITY CALCULATIONS

Condition: ____________

From Table of Hydrostatic Properties:

Displacement = tons

Draft at LCF = ft

LCB (graph reading) = ______+ 432' = LCB = ft

KM_t (graph reading) =

LCF =

MT1 =

TP1 = ft

Trim Calculations: (+Fwd/Aft)

LCG = Ft

Trim = (LCG-LCB) x (Displacement)/(12x(MT1))

= Ft

=

List Calculations: (+ Port - Stbd)(Acc to 7 Deg)

TCG = Ft

List = (TCG) x (57.3)/(GM)

=

Stability Calculations:

VCG = VCG above baseline = ft

Free Surface Correction = Free Surface Moment/Displacement

Free Surface Correction = ft

Available GM:

GM = (KM)-(VCG)-(Free Surface Correction)

GM = ft

Required GM = ft (see Curve page 21)

Draft Calculations:

Draft At FP = (LCF Draft)-(Trim x LCF)/(LBP)

= Ft

Draft at AP = (Draft at FP) + Trim

= Ft

Draft at Fwd Draft Mark = (Draft at FP) + (Trim/LBP)x (Dist to Fwd Draft Mark)

= Ft

Draft at Aft Draft Mark = (Draft at FP) + (Trim/LBP)x (Dist to Aft Draft Mark)

= Ft

CARGO/BALLAST TANK SUMMARY

ITEM	WEIGHT L.TONS	LCG FROM F.P. FT	LONG'L MOMENT FT-L.TONS	VCG ABOVE B.L. FT	VERTICAL MOMENT FT-TONS	TCG FROM C.L. FT	TRANSV. MOMENT FT-L.TONS	FREE SURFACE FT-L.TONS
CREW AND STORES								
Crew and Effects		751.25		75.0		0		
Stores and Consumables		751.25		75.0		0		
TOTAL		751.25		75.0		0		
CARGO OIL TANKS (Density = cu ft/LT)								
#1 P Cargo Tank		122.27				55.23		
#1 S Cargo Tank		122.27				-55.23		
#1 C Cargo Tank		113.55				0		
#2 C Cargo Tank		219.50				0		
#3 P Cargo Tank		354.17				60.70		
#3 S Cargo Tank		354.17				-60.70		
#3 C Cargo Tank		354.17				0		
#4 C Cargo Tank		488.83				0		
#5 P Cargo Tank		604.65				59.81		
#5 S Cargo Tank		604.65				-59.81		
#5 C Cargo Tank		623.44				0		
Port Slop Tank		700.27				56.28		
Stbd Slop Tank		700.27				-56.28		
TOTAL								
FUEL OIL (Density = cu ft/LT)								
Port Fuel Oil Tank		766.68				50.76		
Stbd Fuel Oil Tank		766.68				-50.76		
Low Sulfur Fuel Tank		823.73				-43.46		
DIESEL OIL (Density = cu ft/LT)								
Diesel Oil Storage		823.72				0.46		
TOTAL								
LUBE OIL (Density = cu ft/LT)								
Fwd L.O. Storage Tank		765.00				-30.75		
Aft L.O. Storage Tank		770.00				-30.75		
L.O. Settling Tank		758.75				-30.25		
L.O. Gravity Tank		818.50				.50		
TOTAL								
FRESH & POTABLE WATER								
Inboard Feedwater Tank		830.92				6.62		
Outboard Feedwater Tank		830.00				25.00		
Inboard Pot. Water Tank		831.81				-12.63		
Outboard Pot. Water Tank		830.00				-25.00		
TOTAL								
MISCELLANEOUS								
Engine Room Holding Tank		0.92				-19.26		
Sludge Tank		814.80				7.17		
Sewage		752.50				-25.16		
TOTAL								

APPENDIX 2 - STATISTICAL TREATMENT OF WORKSHOP RESULTS

Stability Examination

Analysis of T-S Test I by Rank (Masters vs Others)*

Masters			Others		
Q. 1	Whole	Whole-1	Q. 1	Whole	Whole-1
2	14	12	0	15	15
7	21	14	3	20	17
7	28	21	4	29	25
20	57	37	9	49	40
10	65	55	4	51	37
11	31	20	15	55	40
			18	71	53
			20	61	41
			20	57	37
			9	53	44
			12	53	41
			17	52	35
			9	45	36
			11	32	21

1. Rank Ordering of Question 1:

0 2 3 4 4 7 7 9 9 9 10 11 11 12 15 17 18 20 20 20

$n_1 = 6$ $U = 1 + 4 + 4 + 7 + 8 + 13 = 37$

$n_2 = 14$ $U^1 = n_1 n_2 - U = 84 - 37 = 47$ which is not significant

critical values of U - (two tailed) ($n_1 = 6$, $n_2 = 14$)

α=.10,21 / α=.05,17 / α=.02,13 / α=.002,6

2. Ranking of Whole:

14 15 20 21 28 29 31 32 45 49 51 52 53 53 55 57 57 61 65 71

$U = 0 + 2 + 2 + 3 + 12 + 13 = 32$ which is also not significant

3. Ranking of Whole- Question 1:

12 14 15 17 20 21 21 25 35 36 37 37 37 40 40 41 41 44 53 55

$U = 0 + 0 + 2 + 3 + 7 + 14 = 26$ not significant

---

* it's important to note that of the 6 masters, 5 were from tankers and only 1 was from a dry cargo vessel (and he had the lowest overall score in that group)

The following conclusions may be drawn regarding the stability examination scores:

(1) Regarding the conceptual questions on <u>initial stability</u> (question 1, parts a-e), the majority of dry cargo personnel scores are significantly ($p < .01$) higher than the scores achieved by tanker personnel. This result obtains from use of the Mann-Whitney U Test (a very commonly used non-parametric analogue to the t test). The significance level is based on a one-tailed test at $\alpha = .01$, consistent with the hypothesized direction of effect.

(2) The majority of dry cargo personnel scores (on the <u>extire exam</u>) are significantly ($p < .02$) higher than the scores achieved by tanker personnel.

(3) The result of the analysis of <u>total test scores less the first question</u> on initial stability is ambiguous. While the dry cargo personnel out-performed tanker personnel, the Mann-Whitney procedure fails to achieve traditional levels of significance using a critical value of U for a two-tailed test at $\alpha = .05$ (the two-tailed criterion consistently reflects the lack of an a priori hypothesis of which group would out-perform which).

Analysis of Data Obtained at MITAGS the week of May 7, 1980:

1. The degree of agreement with statements concerning stability and longitudinal strength (which have truth value) indexes the experiential knowledge of the respondents. This index provides a basis for comparing different ranks (Masters vs Others) and crews of different vessel types (Dry Cargo vs Tanker) on a relevant background characteristic for this study (viz. stability concepts). In the absence of significant differences we may be justified in pooling the opinions and attitudes of these individuals to obtain more precise estimates without jeopardizing their validity significantly.

   The following data reflects the sum of item responses for the first six questions (on Stability Concepts). Item 2 has been re-keyed to reflect the negative truth value of the statement. Omissions have been entered as 3's (i.e. uncertain). Lower scores reflect greater experiential knowledge than higher scores.

Case #	Rank	Vessel Type	Total Score
1	M	Training	19
2	M	Cargo	16
3	M	Tanker	14
4	M	Tanker	16
5	C/M	Tanker	15
6	M	Tanker	15
7	2M	Tanker/ Cargo	13
8	M	Tanker	13
9	M	Tanker	13
10	C/M	Tanker	12
11	2M	Tanker	17

Case #	Rank	Vessel Type	Total Score
12	M	Tanker	15
13	2M	Tanker Cargo	20
14	C/M	Cargo	12
15	C/M	Cargo	18
16	C/M	Cargo	12
17	M	Cargo	10
18	3M	Cargo	16
19	C/M	Cargo	12
20	2M	Tanker	14
21	2M	Cargo	17

1. Comparison of Masters and Others

Ranking of Total Scores

$\underline{10}$ 12 12 12 12 13 $\underline{13}$ 13 14 $\underline{14}$ $\underline{15}$ 15 $\underline{15}$ $\underline{16}$ 16 $\underline{16}$ 17 17 18 $\underline{19}$ 20

$U^1 = 0 + 5 + 7 + 7 + 8 + 8 + 9 + 12 = 56$

$U = n_1 n_2 - U^1 = 8(13) - 56 = 48$ not significant

2. Comparison of Dry Cargo and Tanker Personnel

Ranking of Total Scores*

$\underline{10}$ $\underline{12}$ 12 $\underline{12}$ $\underline{12}$ 13 13 14 14 15 15 15 $\underline{16}$ 16 $\underline{16}$ $\underline{17}$ 17 $\underline{18}$

$U = 0 + 0 + 1 + 1 + 8 + 9 + 9 + 10 = 38$ not significant

Critical Values of U:

1. for $n_1 = 8$, $n_2 = 13$ (two-tailed) -

$\alpha=.002, 11$ / $\alpha=.02, 20$ / $\alpha=.05, 24$ / $\alpha=10, 28$

2. for $n_1 = 8$, $n_2 = 10$ (two-tailed) -

$\alpha=.002, 6$ / $\alpha=.02, 13$ / $\alpha=.05, 17$ / $\alpha=.10, 20$

---

* Some scores have been dropped because of ambiguity in vessel identification.

Question	S.Agree 1	Uncertain 2	3	4	S.Disagree 5	x	Agree	Disagree	% Agreement
1	6	12	1	2	-	1.95	18	2	90%
2	2	10	2	5	1	2.65	12	6	67
3	1	12	3	4	-	2.50	13	4	76
4	4	12	2	3	-	2.19	16	3	84
5	6	9	-	5	1	2.33	15	6	71
6	1	13	3	3	-	2.38	15	3	83
7	2	9	2	8	-	2.76	11	8	58
8	9	9	1	2	-	1.81	18	2	90
9	11	10	-	-	-	1.48	21	0	100
10	14	4	3	-	-	1.48	18	0	100
11	2	2	13	4	-	2.90	4	4	50
12	-	1	11	9	-	3.38	1	9	10
13	2	9	2	6	2	2.86	11	8	58
14	9	11	-	-	1	1.71	20	1	95
15	4	4	4	7	2	2.95	8	9	47
16	4	11	3	3	-	2.24	15	3	83
17	-	6	2	5	1	3.07	6	6	50
18	3	10	2	-	-	1.93	13	-	100
19	1	12	2	-	-	2.07	13	-	100
20	-	6	8	2	-	2.75	6	2	75
21	-	2	5	6	1	3.43	2	7	22
22	3	9	2	1	-	2.07	12	1	92
23	-	7	5	1	-	2.54	7	1	88
24	1	8	5	-	1	2.47	9	1	90
25	-	5	8	3	-	2.88	5	3	63
26	-	7	6	4	-	2.82	7	4	64

Question	Yes	No	% Agreement
27	18	2	90
28	7	13	35
29	15	3	83
30	15	2	88

APPENDIX 3 - THE PHYSICAL AND COGNITIVE BASIS OF GOOD FORMAT

APPENDIX 3 - THE PHYSICAL AND COGNITIVE BASIS OF GOOD FORMAT

1. Physical Basis of Good Format

To be able to use the T&S book effectively, the ship's officer must be able to interpret it visually and understand the instructions. The first problem is one of physical presentation, the second one of comprehensibility. The requirement for clarity in both is a very pressing one. The booklet is used under conditions which make accurate reading as difficult as possible - poor light, vibration, interruptions - and the educational background of the users puts a premium on the use of straightforward language and manageably-sized instructions.

This section discusses the basic physical and linguistic considerations which underlie the contractor's subsequent evaluation of T&S booklets, and recommendations for format and contents improvements.

In order to understand why certain formats can be used more quickly and accurately than others, the perceptual basis of searching must be understood.[1] The retina of the eye, unlike a photographic plate, is not uniformly sensitive. Its center is the fovea, an area of high resolution, with a high density of visual receptors which transmit information to the brain. When a person looks directly at a word or number group, his eyes move so that the image falls on or close to the fovea, when the eyes are said to *fixate* the target. While the eyes are fixated, the brain decides where to move the eyes to next, on the basis of the information available through peripheral vision, which is relatively undiscriminating compared to the fovea. In searching for targets (quantities) in a tabular format, or reading graphs, the level of detail

[1] Philips, R.J. et al (1978).

available from peripheral vision has a direct effect on the number of eye fixations a reader needs to find a specific type of target.

During a search for a specific piece of information, or target, eye movements are rapid. The eyes fixate one unit of information after another until the target is fixated. Records of eye movements show that the eyes occasionally overshoot their target. When this happens, they fixate the target, move to another, where fixation is of short duration, and then return to the target. During a search, visual images are so blurred that it is impossible for the reader to assimilate any information. Between movements, his eyes remain at rest for relatively long periods, which is when 'reading' occurs.

Total search time is the product of the number of targets fixated and the mean duration of one fixation and one movement, plus a constant which accounts for short periods at the beginning and the end of a search. The time taken to make an eye movement, usually about a tenth of the fixation time, is relatively unimportant. The important factors which influence the total search time are(1) the number of fixations, and (2) the mean fixation time.

Factors Which Affect the Number of Fixations

The number of targets which needs to be fixated during a search clearly depends on the search path which the eyes follow and the position and characteristics of the target. Most people begin their search near the top of a page, whatever the format of the material to be examined, so fewer fixations are generally needed to find targets in the upper half of a page. The position of target information and the search path followed in the

pages of the T&S booklet are not presently influenced by graphic design principles, and therefore have a random effect on the number of fixations. Research suggests that the booklet designer has effective ways to reduce the number of targets which need to be fixated, i.e. reducing the information in the search area (whether or not this involves subdividing the area), and typographic coding.

Clearly, halving the amount of information on a page will approximately halve the number of fixations needed to find a particular target. This is not often congruent with the level of detail of required content of the T&S booklet, however. Fortunately, the same end can be achieved by explicitly demarcating and thereby reducing the area which needs to be searched. This leads to consideration of optimal grid configurations, table headings, and scales.

The second way in which a designer can reduce the number of fixations, and hence speed up use of the T&S booklet, is by typographic coding.[1] If various types of information are printed in different type sizes or colors, this will substantially reduce the number of fixations. Typographic coding and optimal choice of grids can clearly save time in finding a target as long as they are meaningful to the reader and appropriate.

Typographic coding affects the number of fixations rather than the mean fixation time.[2] A well-developed scheme of typographic coding allows optimum use of the peripheral vision, for screening information and otherwise facilitating searching. Peripheral vision is best suited to negative functions such as elimination of shapes inconsistent with known target characteristics. Typographic

[1] Bartz (1970). Foster and Kirkland (1971).

[2] Williams, L.G. (1967).

coding by color or type size can reduce the number of fixations only if the reader knows what size or color the target should be. Other kinds of typographic coding, for example, characteristic roman or italic typefaces for specific types of information, are weakly effective.[1] Use of various types of grids - solid, pecked, various thicknesses - is more efficient in speeding the searc.

Factors Which Affect the Mean Fixation Time

Although a number of factors affect mean fixation time, the more difficult a piece of information is to process cognitively, the longer the mean fixation time.

First, if targets fixated closely resemble one another, it will take longer for the brain to decide which is the target. If tank capacities are all displayed to four decimal figures, for example, the time required to use the capacity table will be increased and errors likelier.

Second, design factors affect the difficulty of processing information. The value of typographic differences in assisting comprehension was demonstrated by Bartz and others. For example, the mean fixation time decreases as the print size of the targets increases. Increasing type size predictably improves performance, but in verbal search tasks there is also a strong effect of case.[2] Targets set in lower case with an initial capital are almost 10 percent faster than those in capitals, even though the former present a smaller visual shape.

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1 Suggested by Bartz's work in 1969-70.

2 Philips, R.K. et al (1977).

2. Cognitive Bases of Good Format

The Process of Reading[1]

The normal reader can perceive approximately 24 characters, or about 5 related words, in 10 msecs. This ability is rarely utilized. A reader's average eye span will include less than ten characters, requiring approximately 100 msecs, i.e. ten times longer than is necessary, to perceive. A reader's eyes follow the printed lines in a series of short eye movements followed by pauses, though he has the impression that he is making a single continuous movement. The movements sometimes occur as fast jumps, termed saccadic movements, and sometimes as slow sweeps. Pauses between the movements occupy 90% of the reading time. It is during these fixational pauses that reading as such takes place. The comprehension of meaning, unlike the identification of target information, is a continuous process which is not inhibited while the eye is moving. In the efficient reader, eye movements and pauses occur with a certain regularity and rhythm.

The number of fixations made in each line of print depends on the difficulty of the material and the background of the reader. As a rule, two or three words are recognized at each pause or fixation. A skilled reader recognizes words by their general outline and perceives them not singly but in meaningful phrases. The movement of the eyes is not invariabbly regular. Even an efficient reader occasionally rereads or regresses along a line he has already seen. The sweep of his eyes from the end of one line to the beginning of the next will usually comprise a single accurate movement, and the focal point of the fixation will not necessarily be at the exact beginning

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[1] This section is partly drawn from notes supplied by T.P. Gorman during his appointment to the Department of English, University College, Nairobi.

of the line, but at a point inside the line. He will make use of side or peripheral vision to perceive the word or words at the beginning of the line.

With material arranged in a columnar form, users should be encouraged to practice the use of their vertical, as opposed to their horizontal, vision. Vertical reading is always somewhat faster than horizontal reading under similar conditions. The method does, of course, allow the reader to make use of peripheral as well as the foveal vision. The technique of reading down, not across, a page is impracticable unless the lines are kept to about three inches in length, if full retention is desired.

Level of Difficulty

Many formulas have been devised for estimating the comprehensibility of textual material. One formula (devised by Flesch) relates to lexical and grammatical complexity. Thos formula estimates the average number of syllables in one hundred words, and then the average number of sentences in the same section. If the second result is then divided into the first, a single figure will be obtained, which can be converted to a percentage. This compares the difficulty of texts.

In assessing comprehensibility, however, a further factor - apart from syntactic or morphological complexity - should be taken into account. This is the rate at which separate ideas and/or facts for *retention* are introduced, which affects both speed of reading and retention. The relative percentage of information retained (in terms of the total ideas and facts in the material) is inversely proportionate to the number of different ideas in the material.

Effect of the Structure of Instructions on Performance

Instructions for trim, stability, and strength involve or imply distinct sequences of operations. It is essential that the respective calculations are performed in the correct sequence, which may be specified or merely implied by the instructions. A fundamental question which must be resolved is how many different operations can be sequenced and performed correctly from a continuous instruction. It is important to find not only the maximum number of operations which can be correctly performed, in order, and also, the preferred length of instruction governing the specified sequence of operations. These are related to such factors as the need to establish the effects of actions early in the sequence, the likelihood of alternative courses of action becoming necessary, and of course the levels of mariners' ability and reading skill. Some of the operations are more crucial than others, signalling choices between subsequent actions. Since the T&S booklet instructions appear to be referred to primarily when the user is new to the ship and the operation, a structured step-by-step format would seem to be desirable.

Consider the following instruction for use of roll stabilization tanks:

> "The roll stabilization tanks, by their nature, create a static stability loss when filling and filled. Tanks to be used should be filled or emptied rapidly and continuously. The Salt Water Ballast Stabilizers No. 5, 7, and 9 produce significant stability losses when filled to levels below 25.0 ft. The ballast/deballast sequences described in instruction 10 on pages viii-ix, provide adequate stability at all times for filling and emptying these tanks. Care should be taken, however, to ensure adequate stability for non-standard conditions before filling or emptying these tanks."

This instruction is not only verbally and operationally complex, but is inverted. The crucial part of the instruction appears to relate to use of standard sequences described in pp. viii-ix. However, the whole of the instruction has to be scanned if the correct procedure is to be followed. The most important part of the instruction is "...ensure adequate stability for non-standard conditions..." Since the position of sub-instructions in a written sequence determines the efficiency of recall and performance, there would be advantages in rearranging the order of sub-instructions, in this case, to require evaluation of the vessel's condition before using the ballast sequences of instruction 10.

Factors Governing Effectiveness of Written Instructions[1]

Functional language, suited for instructions, abandon such traditional characteristics of good style as conciseness and variety, primarily in the interests of clarity. Simple (short) declarative active voice sentences are less ambiguous and easier to understand than sentences in the passive voice and negative statements. This suggests that an operational direction such as "Should cargo discharge be delayed, ballasting must be restricted so as not to submerge the load line, in order to maintain the required positive stability" would be better expressed as "Restrict ballasting if cargo discharge is delayed to avoid submerging the load line. Maintain the required positive stability."

[1] Jones, S. (1968).

Negatives

A considerable amount of research has been carried out on the use of negatives in sentences.[1] Negation is a major factor decreasing comprehension. 'Negative information' is generally less efficiently understood and used than positively expressed information, and the use of negatives to convey directions typically leads to more errors of judgement. This problem probably arises because negative information commonly seems nebulous, and because negative statements are generally used to remove some misconception rather than to convey information. Paradoxically, the prohibitive function of negatives contributes to the blocking of responses, seemingly because of the association of use of a negative with 'inhibition'.

Eliminating all negatives from functional language is theoretically possible, but in practice it would not always be advantageous. The familiarity of prohibitive notices such as "No Smoking on Deck' probably enables such negatives to be immediately understood as commands to avoid the proscribed behavior. This is the effect intended, and in this case, the use of the negative is justified.

In instructions for an unfamiliar situation, e.g. operating restrictions in a new vessel, negatives should be avoided. The equivalent positive form of expressing the new ideas is more effective and safer in conveying the designer's intent.

Negatives are sometimes introduced in the interests of verbal economy, e.g. a booklet designer may want to add text to a near full-page table. However, the advantage of a caption achieved by saving words, can be outweighed by the blocking effect of the negative. Verbal economy, even where it reduces memory load, is

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1 Wason, P.C.

seldom an appropriate/safe objective in the functional language of instructions. It is better to be over-explicit than under-explicit, and to pitch the level of the instructions for slower readers, even at the risk of redundancy.

Length of Sentences

An optimal structure and length of sentence ensures efficient processing and recall. The important items of information should appear at the beginning or end of the sentence.

Optimal sentence length is a function of structure - e.g. the complexity of individual clauses, among other things. Long sentences can be more readily understood if replaced by several short clauses or sentences. Even changing a long clause to two shorter co-ordinate clauses has been found to improve recall. Examine this instruction on regulation of ballast tanks.

> TO MINIMIZE FREE SURFACE IN THE VESSEL, BALLAST TANKS SHOULD BE PRESSED UP WHEN FULL. WHEN NOT BALLASTED, IT IS ESSENTIAL THAT ALL TANKS BE MAINTAINED AT MINIMUM CONTENT. (...) If any ballasted tanks are not either pressed up or pumped to minimum content, the appropriate free surface values from pages 13-18 must be considered when evaluating the vessel's stability during the loading and unloading cycles and at sea.

This instruction could be rewritten. Press up ballast tanks to minimize free surface. Empty tanks should be as dry as possible... If any ballast tanks are not pressed up or dry, the free surface correction corresponding to the tank contents should be applied to all stability calculations." This replaces three sentences of 67 words, by three shorter sentences totalling 42 words, which make the instruction more explicit.

Conclusions

The use of T&S booklets can be speeded and made more accurate by guiding the mariner's search path an controlling the rate of presentation of information.

Important information should be visually coded by location or typography. The upper left hand area of pages is the prime location for directions, labels, etc. Type size and case should receive particular attention.

The optimum column width for vertical reading/ scanning is 3".

Instructions should be lexically and syntactically simple. Simple declarative sentences are generally easier to understand than more complex sentence forms. Consistent with this, experimental evidence shows that positive information is more efficient than information expressed negatively. Such negatives as 'not', 'except', 'unless', 'otherwise', etc. should be avoided when possible. An equivalent positive form of instruction may lengthen sentences, and even entail a certain redundancy. However, verbal economy is less important than clarity. In considering the phrasing of instructions conforming to mariners' verbal preferences, or 'self-instructions', should be an important consideration. The importance of self-instructions has been emply demonstrated by experiments.

In the case of sequential tasks, the optimal length of instruction with respect to efficient performance must be determined. For an instruction contained in a single sentence, the experimental evidence suggests that an important item of information should be positioned at the beginning or end. The middle of the sentence tends to be forgotten. The longer the sentence, the more this effect is intensified.

APPENDIX 4

1. International Law Governing Merchant Marine Officer Training.

2. Evidence Regarding Academy Entrants' Ability. Both from the Evidence of the Oversight Report on the Federal Government's Role in Merchant Marine Officer Education. Ad Hoc Select Subcommittee on Maritime Education and Training of the Committee on Merchant Marine and Fisheries, Serial No. 95-E, 1978.

3. Stability Related Courses at Merchant Marine Academies. From Merchant Marine Academy brochures, 1978-79, and course notes and outlines provided by academy instructors.

APPENDIX 4

1. International Law Governing Merchant Marine Officer Training[1]

International law has little to say on the subject of officers' training and qualifications. The only mandatory international provisions now in force are those of the Officers' Competency Certificates Convention, 1936, which merely requires governments to adopt minimum standards for officers' certificates. The 1960 International Conference on the Safety of Life at Sea did recommend that governments oversee maritime training, largely with respect to safety of life - i.e. navaids, life-saving, and firefighting equipment. Governments were implicitly urged to encourage supplementary or refresher courses where the seafaring population included reentrants or technological change warranted it. This potentially influential recommendation was succeeded by ILO/IMCO publication of the "Document for Guidance: An International Maritime Training Guide". This document was revised in 1975, but remains advisory only. IMCO, in conjunction with the ILO, sponsored an International Conference on Training and Certification of Seafarers in London in 1978. This conference promulgated standards which are embodied in the International Convention Standards of Training, Certification, and Watchkeeping for Seafarers, 1978.

Competence in the assessment of stability and use of stability aids is clearly implicit in these conventions and conference proceedings. Detailed specification of a syllabus and implementation of a training program is left to individual governments' marine regulatory agencies. This undoubtedly leads to a fragmented definition of competence - in calculation of stability, as in other

[1] This section draws on Oversight Report 95-E (1978).

professional areas - reflecting the inputs of many different types of organizations.

The 1936 Officers' Competency Certificates Convention - adopted under International Labor Organization (ILO) auspices - has been ratified by only 25 countries, yet is still the governing international law. It requires governments to (i) prescribe minimum ages and (cumulative) periods of professional service for each grade or certificate, and (ii) provide for administration of license/certificate examinations. Transition provisions allow a 3-year grade period in which a government may issue certificates without examinations to sufficiently practically-experienced candidates who have a clean professional record. Vessels under 200 GRT may be exempted. Signatories of the Officers' Competency Certificates Convention include the United States, Liberia, Panama, France, Norway, Italy, Spain, and Denmark. The nonsignatories include the United Kingdom, the U.S.S.R., Greece, Netherlands, Japan, Canada, Sweden, Honduras, Cyprus, Singapore, and Somalia.

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, applies to personnel on virtually all seagoing commercial vessels, and requires parties to issue certificates with international endorsements only to candidates who meet the Convention's detailed requirements for service, age, medical fitness, training, qualification, and examinations. Governments may issue dispensations, in circumstances of exceptional necessity. These allow a person qualified for the next lower cost to fill a vacatn post for up to six months. By a further provision, transitional certificates are allowed. The Convention also contains an article on equivalency. A government may vary its training requirements from those specified

in the annex, if the requirements it enforces ensure comparable professional competence, particularly with respect to pollution prevention.

Although the Convention requires deck and engine officers to show, at five-year maximum intervals, that they have maintained their skills - whether through work experience, training courses, or examinations - it does not require periodic renewal of certificates.

The sea-time requirement certification of deck officers in charge of a watch is three years. Two years may be replaced by an approved training course. The United States currently requires approximately one year of sea time on commercial vessels in conjunction with an approved training course (only 6 months of sea time if it is on a training vessel). The Convention's requirement would enforce major changes in U.S. maritime training if the U.S. became secondary.

Twenty-three resolutions, which are not binding parts of the Convention, were adopted by the conference which negotiated the Convention. These resolutions contain many recommendations for training beyond that required by the Convention itself, including radar simulator training for masters and deck officers, mandatory firefighting training for crews of tank vessels, and ship's bridge simulator training for persons who are about to become masters or chief mates on large ships or ships with unusual handling and maneuvering characteristics. Table 4-1 summarizes the Convention's requirements for stability knowledge in master, mates, and watchkeepers of commercial vessels (technically, all vessels over 200 GRT).

TABLE 4-1

Source: International Conference on Training and Certification of Seafarers, 1978. IMCO, London, 1978. Exerpt from the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, 1978.

APPENDIX TO REGULATION II 2

Minimum knowledge required for certification of masters and chief mates of ships of 200 gross register tons or more

1 The syllabus given below is compiled for examination of candidates for certification as master or chief mate of ships of 200 gross register tons or more. It is intended to expand and extend in depth the subjects contained in Regulation II 4 – "Mandatory Minimum Requirements for Certification of Officers in Charge of a Navigational Watch on Ships of 200 Gross Register Tons or More". Bearing in mind that a master has ultimate responsibility for the safety of the ship, its passengers, crew and cargo, and that a chief mate shall be in a position to assume that responsibility at any time, examination in these subjects shall be designed to test their ability to assimilate all available information that affects the safety of the ship.

8. *Ship stability*, construction and damage control*

(a) Understanding fundamental principles of ship construction and the theories and factors affecting trim and stability and measures necessary to preserve safe trim and stability.

(b) Knowledge of the effect on trim and stability of a ship in the event of damage to and consequent flooding of a compartment and counter measures to be taken.

(c) Demonstrate use of stability, trim and stress tables, diagrams and stress calculating equipment, including knowledge of loading cargoes and ballasting in order to keep hull stresses within acceptable limits.

(d) General knowledge of the principal structural members of a ship and the proper names of the various parts.

(e) Knowledge of IMCO recommendations concerning ship stability.

APPENDIX TO REGULATION II/4

Minimum knowledge required for certification of officers in charge of a navigational watch on ships of 200 gross register tons or more

15. *Ship stability*

(a) Working knowledge and application of stability, trim and stress tables, diagrams and stress calculating equipment.

(b) Understanding of fundamental actions to be taken in the event of partial loss of int[illegible]ct buoyancy.

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* Masters an[illegible] [illegible] mates serving on small ships shall be fully acquainted with the basic stability requireme[illegible] of such ships

2. Evidence Regarding Academy Entrants' Ability

Most of the schools have been receiving increased numbers of applications in recent years, allowing them to be more selective in admissions. Table 4-2 shows an increase in average scholastic aptitude test (SAT) scores for 74-77, which has been even more marked in the 77-78 admissions, when national average scores, in fact, dropped a few percentage points. Additional evidence of the rising academic level of academy entrants is provided by the fact that the state maritime academies and the U.S. Merchant Marine Academy have experienced declining attrition rates during the past three years.

Table 4-3 compares the attrition rate for the 1974 graduating class with that of the 1977 graduating class at the eight MMAS. The overall attrition rate for the class of 1977 was 36 percent, compared with 94 percent for the class of 1974. A typical national attrition rate, for the class of 1976, was 53.2 percent. The national 1977 rate is projected to be a similar or slightly higher figure.

The levels of ability of the high proportion of 'hawse pipe' masters and mates - estimated at 77% in a 1974 Coast Guard survey of 200 vessels - can only be estimated. It seems reasonable to assume that the reading level is high enough to permit full understanding and use of T&S booklets written in functional language The mathematical exposure is more questionable. It is likely that concepts such as correction of the statical stability curve by use of sine and cosine curves are unintelligible to a high proportion of competently serving masters and chief officers. Information from many thoughtful respondants, well placed to assess the level of mathematical sophistication of the present officers, suggests that provision needs to

TABLE 4-2

AVERAGE SAT SCORES

School	Class Entering in 1977		Class Entering in 1974	
	Verbal	Math	Verbal	Math
California	456	515	454	494
Maine	410	487	440	480
Massachusetts	447	515	435	499
New York	480	560	462	532
Texas	505	525	452	558
USMMA (Kings Point)	510	620	510	590
Average of Academy Freshmen	471	549	465	529
Average of All U.S. College Freshmen	429	471	440	478

TABLE 4-3

ATTRITION

School	Entering Freshmen	1977 Graduates	Attrition (percent) Class of 1977	Attrition (percent) Class of 1974
California*	144	100	31	55
Maine	139	107	23	37
Massachusetts	261	171	34	40
New York	191	105	45	55
Texas	32	25	22	37
USMMA (Kings Point)	344	215	38	50

* California data is for 1976 graduating class, since 1976-1977 was transition from 3- to 4-year program, with only 8 students graduating.

be made for intensive short courses in ship trim and stability principles if the trend toward 'complexification' of the task of stability assessment is not to result in mechanistic performance.

3. Stability-Related Courses at Merchant Marine Academies

Table 4-4, consisting of exerpts from the syllabi of stability-related courses at merchant marine academies, is designed to provide a quick appreciation of the available formal instruction . It must be reiterated that the most successful academy courses (in terms of graduates' favorable attitudes and apparent skill) shared several characteristics. There was less direct keying of instruction to a text. Operationally relevant principles were emphasized, and there was an awareness of the intimidating effects of the naval technical vocabulary. Coverage was curtailed to match the time available, so that there was a firm basis for follow-on self-instruction. Direct instruction in licensing requirements was separated from the designed stability curriculum.

TABLE 4-4 STABILITY-RELATED COURSES AT MERCHANT MARINE ACADEMIES

California Maritime Academy

D-207 Naval Architecture

A survey course of ship design and construction emphasizing, nomenclature of the hull and structural components, hull strength, vessel performance and routine drydocking operations.

D-210 Naval Architecture

A study of the statics of naval architecture for ship shape hulls, emphasizing application to stability, trim, volume and moment calculations for determination of intact, upright stability and trim including free surface corrections are introduced prior to a study of stability analysis techniques and criteria. A brief introduction to the naval architecture of non-ship-shape hulls and ship motions is made during the course.

D-309 Transportation Management I

This course is a study of the international movement of dry cargo, and it emphasizes the role that the ship's officer plans as a front line manager in the shipping organization's structure. In relation to both break bulk and container operations, the course covers cargo handling equipment, stowage of various commodities, cargo plans, and planning of stowage, and trim and stability calculations.

D-310 Transportation Management II

This course if a continuation of Transportation Management I and is a study of ocean transportation of bulk liquid cargo. Areas covered include characteristics of petroleum cargo, cargo planning and operations, tanker terminals, pollution control, safety, and Coast Guard regulations.

TABLE 4-4 (continued)

Maine Maritime Academy

NS 4 - Ship Stability, Trim, and Damage Control

Definition of stability and stability terms; initial stability; KG using moments; calculation of KG for a loaded ship; effects of negative GM; calculation of KM; movement of metacenter with transverse inclination; inclining experiment and determination of lightship KG; inclined stability; drawing statical stability curves; analysis of statical stability curves; free surface; causes and effects· control of free surface; free communication and grounding; reserve, buoyancy and floodable length; trimming moment, MT1", change of trim; effects of trim; LCG method of trim calculation; stability and trim computers and tables; practical stability and trim consideration; damage control.

NS 2 - Ship Structure

Introduction to ship construction, naval architecture and related nomenclature. Covers ship types, construction, methods, materials, machinery, and equipment used in shipbuilding and ship operation. Introduction to design, stresses and strains, ship characteristics, tonnages, stability, launching and trials including responsibilities of the various regulatory bodies.

NS 7 - Cargo I

Ship owners' organization for cargo procurement, stowage, care and delivery. Ship officers' responsibilities for cargo handling and stowage. The ship's loading and discharging of various cargoes with handling principles. Ventilation and securing of cargoes.

TABLE 4-4 (continued)

NS 8 - Cargo II

Carriage of special cargoes. Tank vessels and bulk carriers. Special grain carriage regulations. Distribution of cargoes with regard to stability and load lines. Cargo containerization. LASH systems, roll on-roll off carriage of cargoes. Research and developments in the industry in relation to the carriage of cargo. Cargocaire systems.

Massachusetts Maritime Academy

Naval Architecture I 644, Ship Construction

Elements of modern ship design, construction and operation. Principal dimensions, ship types and trends in design. Tonnage calculations. Classification effect on ship design. Freeboard and load line regulations. Materials used for ship construction, stresses and strains produced. Lines drawing and offsets. Techniques of riveting and welding. Ship tanks and piping systems. Ship control and rudder characteristics. Launching and drydocking, weight and displacement calculations. Motion of ships in waves. Resistance and calculation of ship horsepower. Propellers and propulsive efficiency. Ship's trials.

Naval Architecture II 646, Stability and Trim

Ship stability and trim. Define terms related to the flotation properties of a ship. Study of forces and mathematics for determining and using centers of gravity and buoyancy, metacentric height, metacenter equilibrium, and initial stability. Procedure and results of an inclining experiment. Construction

TABLE 4-4 (continued)

of cross and statical stability curves. Range of stability. Surface and volume permeability. Impairment of stability. Floodable length curves. Use of stability and trim computers and solution of practical stability and trim problems.

Cargo I 634

Types of cargo and ship designs for handling cargo. Standard cargo rigs. Cargo plans. Load lines. Stowage and hold procedures. Stevedoring terms. Trim and seaworthiness. Manifests. Dangerous cargo regulations. Terminal operations. Mate's responsibility. Safety Laboratory on training ship.

Cargo II 641

A complete survey of tanker operations and handling liquid cargoes. Development and description of the tankship vessel. Pipeline systems of various size and types of tankers. Classification and measurement of liquid cargo. Transfer operations. A mate's responsibility during loading, discharging, and ballasting. Tank cleaning methods and procedures. Tanker safety requirements. Pollution control procedures. Tanker problems on stress, trim and fresh water allowance. Automated and semi-automated liquid cargo equipment.

Maritime Academy, Great Lakes - Synopsis of Instructor

Definition of stability; calculation of GM, KM; the inclining experiment; stability at large angles of heel; free surface; damage stability; trim; stability and trim computers and tables; practical stability and trim considerations. Marine disasters.

TABLE 4-4 (continued)

Moody College (Texas A&M)

Naval Architecture I

Description of ship as self-sustaining unit. Shipbuilding nomenclature and dimensions, type of construction and classification of merchant ships. Classification societies, shipbuilding materials and methods, and structural components of ship.

Naval Architecture II

Ship's lines drawing and form calculations; principles of floation and buoyancy; inclining experiments, free liquids, transverse stability; motion of ships in waves, seaway and dynamic loads, ship structure tests.

Marine Cargo Operations I

Objectives and problems with break bulk cargo handling during loading, discharging and in-transit carriage. Requirements of special refrigerated and dangerous cargoes. Heavy lift operations with conventional cargo gear and its restraints. Cargo loss prevention, safety and related documentation, as well as log book entries. Modern cargo concepts - containerization, roll-on/roll-off, LASH, and others. Maximum cargo efficiency with relation to space, cargo gear, crew and labor costs. Practical cargo gear use and cargo observations during lab periods.

Marine Cargo Operations II

Principles and practice of bulk liquid and gas handling and carriage by water craft. Theoretical and practical problems involved in loading, stowing, and discharging of petroleum, chemical, elevated

TABLE 4-4 (continued)

temperature and cryogenic cargoes. Attention paid to marine pollution abatement, personnel safety and firefighting techniques and systems.

SUNY - Ft. Schuyler

Engineering 301

Description of structural components, types of construction, materials, and methods of shipbuilding. Principles of ship form, flotation, transverse and longitudinal stability. Merchant marine practice in stability and trim calculations for intact and damaged vessels.

Marine Transportation 201

Principles and problems of stowage and carriage of general, bulk (dry and liquid), refrigerated, and special cargoes; a complete project in the actual loading and stowage of a vessel is required. Introduction to tanker operations.

STANDARD ABBREVIATIONS AND SYMBOLS

K	The keel
B	The center of buoyancy when the ship is upright
B_1	The center of buoyancy when the ship is inclined
BM or BM_T	The height of the transverse metacenter above the center of buoyancy
BM_L	The height of the longitudinal metacenter above the center of buoyancy
CB	Center of buoyancy
G	The original position of the center of gravity
G_1	The new position of the center of gravity
M	The original position of the transverse metacenter
M_1	The new position
M_L	The longitudinal metacenter
KB	The height of the center of buoyancy above the keel
KG	The height of the center of gravity above the keel
Kg	The height of the center of gravity of an item above keel
KM	The height of the transverse metacenter above the keel
GM	Initial transverse metacentric height
CF	Center of Flotation
GZ	The length of the righting lever about center of gravity
KN	The length of the righting lever about keel
V or ∇	The ship's volume of displacement
W or Δ	The ship's weight of displacement
w	A weight to be loaded, discharged, or shifted

	Amidships. (The symbol is shown on trim diagrams)
L	The ship's length
B	The ship's maximum beam
F	Forward, or center of flotation
D	The ship's depth
d	The ship's draft
A	Aft
M or m	Mean
C_w	The water-plane coefficient
C_b	Block coefficient
C_m	Coefficient of midships area
C_p	Prismatic coefficient
I or i	Second moment of an area
ℓ	The distance of the center of flotation from aft
P	The upthrust on the keel blocks when drydocking
p	The permeability of a compartment
WL	The original waterline
W_1L_1	The new waterline
G_v	The virtual center of gravity
t	The trim
MCTC or MCT 1 cm	The moment to change the trim by 1 centimeter
TPC	The tons per centimeter immersion
GM_L or LGM	The longitudinal metacentric height
ρ	Rho, density of fluid
SG	Specific gravity
θ	An angle of list or heel
A	Area of a water-plane
FWA	Fresh water allowance
FW	Fresh Water
SW	Salt Water

CDB	Cellular double-bottom tank
h	The common interval used in Simpson's Rules
E	Young's Modulus
y	Depth from the neutral layer
f	Stress
q	Shearing stress

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GLOSSARY

BENDING MOMENT - The net moment of (shear) forces tending to hog or sag the vessel, measured at a particular station, or section of the vessel.

BULKHEAD DECK - The highest deck to which watertight subdivision is carried (subdivision is accomplished by transverse waterlift bulkheads, hence the name).

CURVE OF FLOODABLE LENGTHS - A curve the length of whose ordinate at any point represents the floodable length centered on that point in the ship's overall length.

FREE SURFACE EFFECT - Loss of GM, due to apparent rise of G. This occurs, for example, when a vessel heels and the liquid in any slack tanks runs to the lower side.

DYNAMICAL STABILITY - The work which must be done in order to heel the vessel to a certain angle.

FLOODABLE LENGTH - The maximum length of compartment which can be flooded, yet permit the damaged vessel to float at a waterline tangential to the margin line (a hypothetical line 3" below and parallel to the bulkhead deck).

FREEBOARD - The height amidships of the 'freeboard deck' (g.v.) above the summer load waterline.

FREEBOARD DECK - The highest complete deck with permanent watertight closures.

FRESH WATER ALLOWANCE - A temporary increase in draft, allowed to a vessel loaded in fresh water, reflecting the fact that fresh water is less dense than seawater so a vessel will sink deeper to displace an equal weight of water.

GM - See metacentric height.

LOADING MANUAL - Certain classes of sophisticated vessels - containerships, tankers with segregated ballast, etc. - are required to have a classification society approved guide to vessel operations. This is variously called the loading manual, operating manual, longitudinal strength manual, or ABS manual. Its many colloquial names sometimes lead to its being confused with such booklets as the ship's characteristics pamphlet and ship owner's operating manual.

LOADLINE - Depth to which the vessel may sink after loading; loadlines are assigned for various ocean zones, and an allowance (the fresh water allowance, FWA) is made for sinkage in brackish or fresh waters of ports and rivers.

METACENTER - For a symmetrical ship inclined to a small angle of heel, a vertical line through the center of buoyancy intersects the ship's centerline plane at the transverse metacenter. More generally, the metacenter represents the local center of curvature of the locus of centers of buoyancy for changing angle of heel.

METACENTRIC HEIGHT ($\overline{GM}$) - The vertical distance from the center of gravity of a vessel (G) to the metacenter (M). In order to be in a condition of statical stability, the metacentric height $\overline{GM}$ must be positive (i.e. the metacenter must be above the center of gravity).

MOLDED DIMENSIONS - Vessel's dimensions taken to the inside of the shell plating (cf. extreme dimensions, taken at outside of plating and extremes of vessel e.g. LOA, length of overall).

PERMEABILITY - The ratio of the volume of water which can enter a given compartment to the compartment's volume - a fully loaded compartment could have permeability ranging from 0% upwards, depending on the space occupied by the cargo or stores.

SHEAR FORCE - The vertical shear force at any transverse section of a beam (or ship) is equal to the algebraic sum of vertical forces to either side of the section.

SHIP OPERATOR - This normally infers to the ship (owner) operator, though it can contextually mean the ship's officers.

SLACK (TANKS) - A partially filled tank has a free surface in proportion to the cube of its breadth. The free surface can be small or reach some maximum value, which is the (fully) slack value. Fuel oil and other oil tanks cannot be completely filled because allowance is required for expansion of the oil, so a free surface correction representing a 98% filled condition, with the vessel hulling 5° is either included in the booklet or incorporated in the lightship (g.v.).

STABILITY LETTER - Letter issued by the district Merchant Marine Technical division of the Coast Guard, defining acceptable loading configurations. If the vessel's safe operation is complex and warrants a more detailed response than a letter

(usually the case), a T&S booklet (g.v.) is issued and incorporated by reference.

STATICAL STABILITY CURVE - Plot of GZ (righting arm) levers against angle of heel.

STRESS - The force per unit area in a material defined at a given point on a particular reference plane in a particular direction. A bar of uniform cross section "A" subject to a pull of "P" experiences a uniform axial tensile stress of P/A everywhere along its length.

TEU - Twenty-foot (container) equivalent units: a measure of containership capacity.

T&S BOOKLET - The Coast Guard approved compendium of information intended to ensure safe operation of a vessel, which may or may not include the classification society approved loading manual and ship operating company instructions.

TONNAGE - Displacement - actual tonnage of water displaced by the vessel deadweight - difference in displacement in light load conditions, i.e. actual ship's capacity to carry cargo and stores.

Typographical Glossary

ASCENDERS - Upward strokes on letters and numbers (conversely, descenders are strokes which dip below the base line).

CASE - Upper case is capital letters, lower is ordinary letters.

FONT - A complete alphabet of type; all fonts of one type constitute a family.

LEADING - Spacing between lines (1-4 points in size is normal although leading is available up to 36 points).

SERIFS - Extrusions on ends of letters.

TYPE - 12 points = 1 pica (a point is a depth measure, 72 to the inch). 6 picas = 1 inch.

TYPEFACE - 'Style' of print, weight of lines, etc.

TYPE SIZE - Size of print, measured in points (72 to the inch).